
VIA VERITAS VITA
THEO LOGIA
CINA MEDI
ARTES LIBER ALES
JUS
AB ANIMO
CALIGINEM
DISPELLERE

REPORT

BY THE

GENERAL BOARD OF HEALTH

ON THE

SUPPLY OF WATER

TO

THE METROPOLIS.

Presented to both Houses of Parliament by Command of Her Majesty.

LONDON:
PRINTED BY W. CLOWES AND SONS, STAMFORD STREET,
FOR HER MAJESTY'S STATIONERY OFFICE.
1850.

LIST OF PLANS.

CONTENTS.

REPORT.

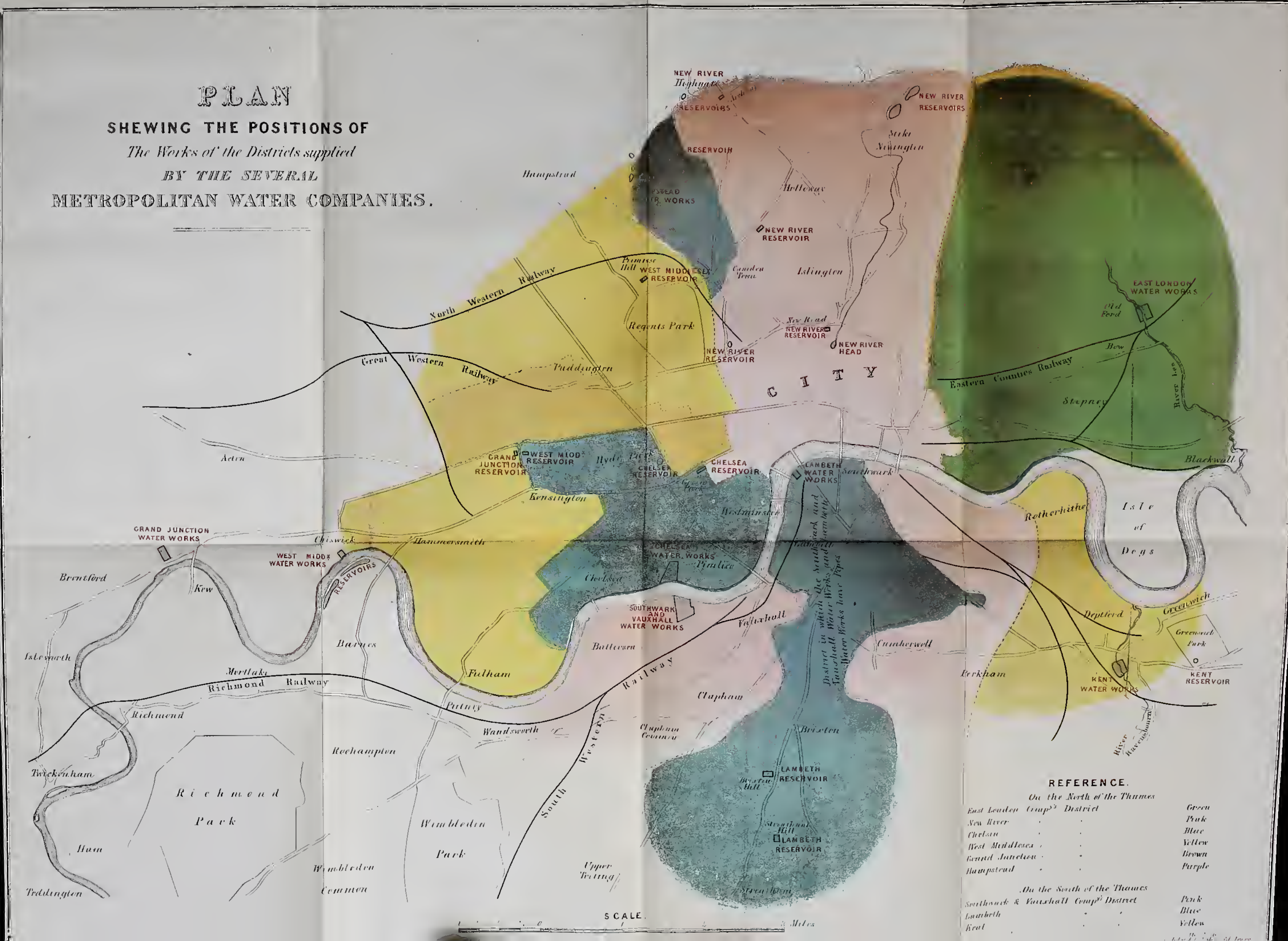
May it please your Majesty:

The members of the Metropolitan Sanitary Commission having addressed themselves to the first topic of their inquiry—the preliminary measures requisite for the better drainage of the metropolis—were proceeding with the second subject of investigation included in the terms of the Commission, namely:—the examination of the means for "The better supply" of the Metropolis "with water for domestic use, for "flushing sewers and drains, and for cleansing streets; "and also the best means of using existing works, and "of erecting any new works requisite, and maintaining "them in action;" when their course was interrupted, first, by the severe visitation of the epidemic influenza, and next, by the approach of the epidemic cholera; the duty of considering the means of averting or mitigating the ravages of these diseases being most urgent and admitting of no delay. Subsequently, during the actual epidemic visitation, their attention, as members of the General Board of Health, was constantly called to the inferior quality and the deficient quantity of the water supplied to the Metropolis, as well as to its defective distribution;—that distribution often necessarily involving deficiency in quantity; and on numerous occasions the effect of polluted waters in causing a dreadful excess of mortality was forcibly brought under their notice. The necessity of improvements in the existing provisions, especially for the supply of houses occupied by the poorest classes, has been very generally and earnestly felt and expressed. It having been submitted to Your

Majesty that the investigation of the best means of improving the supplies of water and of arriving at satisfactory and practical conclusions as to the other topics of sanitary inquiry might be most advantageously completed by the General Board of Health, as now organized, with the services of such of its staff of officers as might be made available, the duty of proceeding with this investigation has devolved upon us; and as Members of the General Board of Health we now humbly beg leave to report as follows:—

In submitting this our Report, we have to bespeak attention to the exposition of several topics which have not hitherto been viewed as connected with measures for the supply of water to towns. We have found it necessary to consider works for the supply of water in connexion with works for the removal of soil and waste water, on which depends the drainage of the sites of houses, and to examine each as part of one system of works requisite for the improvement of the sanitary condition of a town population. The investigation which it has become our duty to complete was commenced in connexion with those works, and would have followed immediately the First Report but for the demands on our attention occasioned by the recent epidemic visitation. We find it now the more necessary to enter, *de novo*, into the exposition of the connexion of water supply with other works, inasmuch as the consideration of that connexion and several public wants hitherto little regarded has led us to new conclusions in respect to the quantities and qualities of water required in many respects opposed to those contained in any of the schemes proposed for the introduction of additional supplies of water for the metropolis.

We trust, that the fulness of the following exposition of the principles which should regulate a water supply for towns, though it has increased the length of the Report, may be justified by the importance of the subject, inasmuch as it may be found useful not for the guidance of the metropolis alone but also for that of Local Boards of Health in provincial towns under


PLAN
SHEWING THE POSITIONS OF
The Works of the Districts supplied
BY THE SEVERAL
METROPOLITAN WATER COMPANIES.
NEW RIVER
Highgate
RESERVOIRS
NEW RIVER RESERVOIRS
Stoke Newington
RESERVOIR
Hampstead
Holloway
NEW RIVER RESERVOIR
Primrose Hill
WEST MIDDLESEX RESERVOIR
Camden Town
Islington
North Western Railway
EAST LONDON WATER WORKS
Old Ford
Regents Park
New Road
NEW RIVER RESERVOIR
NEW RIVER HEAD
Bow
Great Western Railway
Paddington
CITY
Eastern Counties Railway
Stepney
River Lea
Acton
GRAND JUNCTION RESERVOIR
WEST MIDDX RESERVOIR
Hyde Park
CHELSEA RESERVOIR
LAMBETH WATER WORKS
Southwark
Blackwall
Kensington
Westminster
Rotherhithe
Isle of Dogs
GRAND JUNCTION WATER WORKS
Chiswick
Hammersmith
WEST MIDDX WATER WORKS
RESERVOIRS
CHELSEA WATER WORKS
Pimlico
Chelsea
Brentford
Kew
SOUTHWARK AND VAUXHALL WATER WORKS
Vauxhall
District in which the Southwark and Vauxhall Water Works and Lambeth Water Works have Pipes
Deptford
Greenwich
Greenwich Park
Isleworth
Barnes
Battersea
Camberwell
Mortlake
Richmond Railway
Fulham
Peckham
KENT WATER WORKS
KENT RESERVOIR
Putney
Clapham
Richmond
Wandsworth
Clapham Common
Brixton
South Western Railway
River Ravensbourne
Roehampton
Twickenham
LAMBETH RESERVOIR
Brixton Hill
Richmond Park
Wimbledon Park
Streatham Hill
LAMBETH RESERVOIR
Ham
Wimbledon Common
Upper Tooting
Streatham
Teddington
SCALE.
Miles
REFERENCE.
On the North of the Thames
East London Compy's District — Green
New River — Pink
Chelsea — Blue
West Middlesex — Yellow
Grand Junction — Brown
Hampstead — Purple
On the South of the Thames
Southwark & Vauxhall Compy's District — Pink
Lambeth — Blue
Kent — Yellow

the Public Health Act. The applications made to us, from time to time for information and suggestion on the several branches of this inquiry and particularly for any instructional documents or results of experience for the use of foreign engineers, with reference to contemplated sanitary improvements in continental cities, encourage the hope that any exemplification of sound, efficient, and economical principles of such improvements which the Metropolis may afford may have an important influence even beyond the British dominions.

We propose to submit the results of our investigation in the following order:—

First, as to the sources, quantities, and qualities of water at present supplied or proposed to be supplied, and as to the best available sources of supply.

Secondly, as to the mode of distribution now adopted, and as to the influence of the mode of distribution upon the quantity of water required for the metropolis.

Thirdly, as to the mode of removing water after it has been used and discharged, especially as regards the damp and low lying districts of the metropolis.

Fourthly, as to the advantages of a system of constant supply for surface cleansing, diminution of risk from fire, and new applications of water as a source of power.

Fifthly, as to the advantages in economy and efficiency of combined works for water-supply and drainage over the present system of independent works for these purposes, and as to the best administrative machinery for carrying out such a system of combined works.

I. And first, as to the sources, quantities, and qualities of water at present supplied or proposed to be supplied, and the best available sources of supply.

The metropolis is divided into districts supplied by the several Companies as exhibited in the following table:—

NAME OF COMPANY.	District Supplied.	Points from which they take their Supply.	Population of the Towns and Villages draining into the Rivers above the Sources of Supply.	Position of Reservoirs.
New River Company .	Whole of Central London from the boundary of the East London Company (running in a line extending directly north from the Tower to Stamford-hill) on the east, to Charing-cross on the west, and northwards by Tottenham-court-road to Camden-town.	Chadwell spring near Ware, the Lea, Spital-brook, and other small springs taken into the river; the water-shed of the North-hall district, and four deep wells sunk into the chalk in Middlesex and Hertfordshire (two being in Great Amwell).	44,000	Stamford Hill. Highgate Hill. Highgate Archway. Maiden-lane. Pentonville. Hampstead-road.
East London . . .	The east of London, from the Lea on the east, to a line extending directly north from the Tower to Stamford-hill. The district includes Limehouse, Stepney, Poplar, Bromley, Bethnal-green, Hackney, Homerton, Clapton, &c.	The Lea (except 1 per cent. of the whole quantity taken from a branch of that river, namely, the water-works stream).	113,000	Old Ford.
Southwark & Vauxhall	The borough of Southwark, and the parishes eastward of the borough as far as Rotherhithe, and south as far as Camberwell; portions of Lambeth and Clapham, and the whole of Battersea.*	The Thames, near the Red House, Battersea.	788,000	Battersea.
West Middlesex . .	The district west of Tottenham-court-road, and north of Oxford-street, as far as the Edgeware-road; the district also includes Portland-town, Kilburn, West-end, and other adjoining parts.	The Thames (through two subsiding reservoirs in the parish of Barnes, near Barnes-terrace).	646,000	Barnes. Primrose Hill. Camden Hill.

* The central part of the district supplied by the Southwark and Vauxhall Company is supplied also by the Lambeth Company.

NAME OF COMPANY.	District Supplied.	Points from which they take their Supply.	Population of the Towns and Villages, draining into the Rivers above the Sources of Supply.	Position of Reservoirs.
LAMBETH	The larger part of Lambeth, and extending southward to Brixton, including the greater portions of Kennington, Newington, and Walworth.	The Thames at Lambeth.	1,300,000	Brixton Hill. Streatham Hill.
CHELSEA	The west of London from the boundary of the Grand Junction on the north to the Thames, including in the district Chelsea, Little Chelsea, a large part of Westminster, Knightsbridge, &c.	The Thames (by conduit pipe across the bed of the river, beyond mid-stream, near the Red House, Battersea).	788,000	Chelsea. Hyde Park. Green Park.
GRAND JUNCTION . .	St. George's Hanover-square, north of Piccadilly, a small portion of Marylebone, the larger part of Paddington, and St. James's to Pall-mall.	The Thames 360 yards above Kew-bridge.	639,000	Kew. Camden Hill.
KENT	Parts of Camberwell and Rotherhithe; the parishes of St. Paul and St. Nicholas, Deptford; Greenwich and Woolwich; parts of Lee, Lewisham, Charlton, and Plumstead.	The Ravensbourne, below Lewisham.	22,200	Deptford. Greenwick Park.
HAMPSTEAD	Kentish-town and Camden-town .	Springs at Hampstead, Caen Wood, two artesian wells, and (temporarily) the New River.	. . .	Hampstead.

The following tables have been compiled from the returns of the whole of the existing Metropolitan Water Companies. The first table exhibits the gross and the second the average daily supply and chief applications of the water, so far as the Companies are able to distinguish them.

Company.	Houses.	Large Consumers.	Gross Daily Supply for every Day (365) in the Year.					
			Private House.	Large Consumers.	Road Watering.	Flushing &c.	Fires, &c.	Total.
	No.	No.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.
NEW RIVER . .	83,206	444	13,174,484	787,659	124,413	35,360	27,402	14,149,315
Proportion to total	1/3	..	1/1·07	1/17·97	1/114·12	1/404·88	1/515·30	1/2·85
Per cent. . .	33·32	..	93·10	5·56	0·87	0·24	0·19	34·98
EAST LONDON . .	56,409	256	7,891,648	766,674	31,413	63,013	76,712	8,829,462
Proportion to total	1/4·42	..	1/1·11	1/11·51	1/284·58	1/141	1/115	1/4·58
Per cent. . .	22·59	..	89 38	8·68	0·35	0·709	0·86	21·83
SOUTHWARK and VAUXHALL .	34,217	647	4,985,615	838,512	118,356	71,232	..	6,013,716
Proportion to total	1/7·19	.. -	1/1·20	1/7·17	1/50·94	1/84·49	..	1/6·72
Per cent. . .	13·70	..	82·90	13·94	1·96	1·18	..	14·86
WEST MIDDLESEX .	24,480	..	3,038,162	35,131	71,756	168,767	..	3,334,054
Proportion to total	1/10·19	..	1/1·09	1/60·53	1/46·48	1/19·76	..	1/12·13
Per cent. . .	9·80	..	91·18	1·65	2·15	5·05	..	8 24
LAMBETH . .	23,396	147	2,500,753	105,205	78,356	28,767	19,178	3,077,260
Proportion to total	1/10·67	..	1/1·23	1/6·83	1/39·28	1/106·93	1/160·40	1/13·14
Per cent. . .	9·37	..	81·25	14 62	2·53	0·93	0·62	7·60
CHELSEA . . .	20,893	..	3,530,290	257,192	98,614	40,950	13,6 8	3,940,730
Proportion to total	1/12·95	..	1/1·116	1/15·32	1/89·96	1/96·23	1/287·97	..
Per cent. . .	7·72	..	89·57	6·52	2·50	1·04	0 347	..
GRAND JUNCTION .	13,858	200	3,080,424	229,369	150,575	70,958	684	3,532,013
Proportion to total	1/18	..	1/1·14	1/15·40	1/23·38	1/49·77	1/5201·42	1/11·45
Per cent. . .	5·55	..	87·21	6·49	4·26	2·00	0·019	8·73
KENT	9,632	13	970,250	37,490	61,698	9,379	493	1,079,311
Proportion to total	1/25·92	..	1/1·11	1/28·80	1/17·50	1/115·51	1/21·97	1/87·47
Per cent. . .	3·85	..	89·89	3·47	5·71	0 86	0·045	2·66
HAMPSTEAD . .	4,490	..	402,452	2,572	18,522	3,920	..	427,468
Proportion to total	1/55·6	..	1/1·06	1/167	1/23·10	1/109·42	..	1/94 6
Per cent. . .	1·79	..	94 14	0·59	4·32	0·91	..	1·05
Total . . .	270,581	..	39574,081	3,424,707	753,707	492,350	..	44,383,332

Company.	Gross No. of Private Houses.	Daily Delivery (1849) per House for 365 Days in the Year, under the Heads of: Private Houses.	Large Consumers.	Road Watering.	Flushing, &c.	Fires, &c.	Total.
		Gallons	Gallons.	Gallons.	Gallons	Gallons.	Gallons.
NEW RIVER	83,206	158·33	9·46	1·49	0·42	0·33	170·05
Proportion to total	1/3	1/1·07	1/17·97	1/114·12	1/404·88	1/515·30	..
Per cent.	33·32	93·10	5·56	0·87	0 24	0·19	..
EAST LONDON	56,409	139·90	13·59	0·55	1·11	1·36	156·52
Proportion to total	1/4·42	1/1·11	1/11·51	1/284·58	1/141	1/115	..
Per cent.	22·59	89·38	8·68	0·35	0·709	0·86	..
SOUTHWARK & VAUXHALL	34,217	145·70	24·50	3·45	2·08	..	175·75
Proportion to total	1/7·29	1/1·20	1/7·17	1/50·94	1/84·49	..	..
Per cent.	13·70	82·90	13·94	1·96	1·18	..	..
WEST MIDDLESEX	24,480	124·18	2·25	2·93	6·89	..	136·19
Proportion to total	1/10·19	1/1·09	1/60·53	1/46·48	1/19·76	..	..
Per cent.	9·80	91·18	1·65	2·15	5·05	..	..
LAMBETH	23,396	106·88	19·24	3·34	1·23	0·82	131·53
Proportion to total	1/10·67	1/1·23	1/6·83	1/39·38	1/106·93	1/160·40	..
Per cent.	9·37	81·25	14·62	2 53	0·93	0·62	..
CHELSEA	20,893	168·97	12·31	4·72	1·96	0·655	186·62
Proportion to total	1/12·95	1/1·116	1/15·32	1/39·96	1/96·23	1/287·57	..
Per cent.	7·72	89·57	6·52	2·50	1 04	0·347	..
GRAND JUNCTION	13,853	222·28	16·55	10·86	5·12	0·049	254·87
Proportion to total	1/18	1/1·14	1/15·40	1/23·33	1/49·77	1/5201·42	..
Per cent.	5·55	87·21	6·49	4·26	2·00	0·019	..
KENT	9,632	100·73	3·89	6·40	0·97	0·051	112·05
Proportion to total	1/25·92	1/1·11	1/28·80	1/17·50	1/115·51	1/2197	..
Per cent.	3·85	89 89	3 47	5·71	0·86	0·045	..
HAMPSTEAD	4,490	89·63	0·57	4·12	0·87	..	95·20
Proportion to total	1/55·6	1/1·06	1/167	1/23·10	1/109·42	..	..
Per cent.	1·79	94·14	0·59	4·32	0·91	..	..
Total	270,581	..	..	..	..	..	..
Average	..	146·25	12·65	2·78	1·82	0·51	164·03
Proportion to total	..	1/1·12	1/12·96	1/59	1/90·12	1/321·62	..
Per cent.	..	89·28	7·71	1·69	1·10	30·1	..

The PROPORTIONS which the Supply to Private Houses bears to the Total Supply, and the Proportions due to all other sources are as follows, viz. :—

COMPANY.	Private House Supply.	All other Supplies.	COMPANY.	Private House Supply.	All other Supplies.
	per Cent.	perCent.		per Cent.	perCent.
New River	93	7	Grand Junction . . .	87	13
East London . . .	89	11	Kent	90	10
Southwark and Vauxhall .	83	17	Hampstead	94	6
West Middlesex . . .	91	9			
Lambeth	81	19	Average . .	89	11
Chelsea	90	10			

According to these returns, the Companies supply 270,581 private houses. The total number of houses returned under the income-tax assessments for the metropolis, is 288,037, so that as far as these returns enable us to judge there appear to be 17,456 houses (or about six per cent. of the whole) unsupplied with water. Where house-to-house inquiries have been made for sanitary purposes, in densely populated districts upwards of 18 per cent. of the houses have been found to be unsupplied with pipe water ; but, in other large parishes and districts, only five, four, and three per cent. There are, however, returned by the Companies 1,181 cases of supply by stand-pipes, which each serve for several houses and often for a whole court or alley, which houses may be comprised in the Companies' returns, and omitted in those obtained by house-to-house inquiries. With allowances for these discrepancies, we have seen no grounds to doubt the general fairness of the returns made to us, on these points, by the Companies.

The following table includes the whole of the houses returned under the income tax assessment, and displays the proportion of each class of tenements, as denoted by the rental, to the other classes amongst whom the supplies are distributed. It furnishes the means of estimating the proportionate amount of contribution from each class to an equal assessment, and it displays how much more is to be obtained by fair general contribution than by charges on the higher classes of houses. It is to be observed, however, that a far larger proportion of the houses in the metropolis are occupied by the labouring classes than might be judged by the rental to be so occupied, inasmuch as a large proportion of the two,

three, and four storied, and even larger houses are let off in separate floors, and often in single rooms to single families. In such instances the supply by one butt in a yard, or area, is equivalent only to a supply by a common stand-pipe to several houses in a court or alley.

SUMMARY of TABLES, showing the Number of Houses in the Metropolis in Classes according to Rental; the Amount of Assessment, and the Proportion that each Class bears to the Total Number of Houses; and to the Total Amount proposed to be levied by a Penny Rate.

AMOUNT OF ASSESSMENT.	Total Assessment of each Class.	Number of Houses computed from the Number of Persons* Assessed.	Proportion of each Class of Houses to the Total Number of Houses.		Gross Produce of a Penny Rate from each Class of Houses.	Average Charge to each House per Annum.	Proportion of the Money Produce of each Class to the Total.	
			Per Cent.	About			Per Cent.	About
£.	£.				£. s. d.	£. s. d.		
£. Under 10	361,039	64,023	22·2	1/5	1,504 6 7	0 0 5	3·0	1/33
10 and under 20	702,018	48,531	16·8	1/6	2,925 1 6	0 1 3	5·8	1/17
20 ,, 30	1,177,251	50,306	17·5	1/6	4,905 4 3	0 2 1	9·7	1/10
30 ,, 40	1,097,679	33,921	11·8	1/9	4,573 13 3	0 2 11	9·0	1/11
40 ,, 50	965,337	22,885	7·9	1/13	4,022 4 9	0 3 9	7·9	1/12
50 ,, 60	820,614	15,750	5·5	1/19	3,419 4 6	0 4 7	6·7	1/15
60 ,, 70	726,250	11,724	4·1	1/24	3,026 0 10	0 5 5	5·9	1/16
70 ,, 80	533,766	7,382	2·6	1/39	2,224 0 6	0 6 3	4·4	1/22
80 ,, 90	507,146	6,200	2·2	1/46	2,113 2 2	0 7 1	4·2	1/24
90 ,, 100	297,095	3,232	1·1	1/89	1,237 17 11	0 7 11	2·4	1/41
100 ,, 120	710,872	6,767	2·3	1/43	2,961 19 4	0 9 2	5·8	1/17
120 ,, 140	528,681	4,209	1·5	1/68	2,202 16 9	0 10 10	4·3	1/23
140 ,, 160	453,864	3,088	1·0	1/93	1,891 2 0	0 12 6	3·7	1/26
160 ,, 180	264,648	1,603	·6	1/179	1,102 14 0	0 14 2	2·2	1/46
180 ,, 200	202,702	1,095	·4	1/263	844 11 10	0 15 10	1·7	1/60
200 ,, 250	593,813	2,774	1·0	1/104	2,474 4 5	0 18 9	4·9	1/20
250 ,, 300	369,475	1,392	·5	1/207	1,539 9 7	1 2 11	3·0	1/33
300 ,, 350	317,452	1,016	·3	1/283	1,322 14 4	1 7 1	2·6	1/38
350 ,, 400	173,780	483	·2	1/603	724 1 8	1 11 3	1·4	1/70
400 ,, 500	265,447	624	·2	1/463	1,106 0 7	1 17 6	2·2	1/45
500 ,, 600	190,607	364	·1	1/791	794 3 11	2 5 10	1·6	1/64
600 ,, 700	117,263	188	·06	1/1538	488 11 11	2 14 2	1·0	1/104
700 ,, 800	77,170	105	·03	1/2777	321 10 10	3 2 6	·6	1/155
800 ,, 900	69,650	86	·02	1/3348	290 4 2	3 10 10	·6	1/175
900 ,, 1,000	45,553	49	·01	1/5882	189 16 1	3 19 2	·4	1/263
1,000 and upwards .	617,336	240	·08	1/1203	2,572 4 8	4 11 8	5·0	1/19
Total . .	12,186,508	288,037	100	. .	50,777 2 4	0 3 6¼	100	. .
Average rental of houses in the metropolis.	£. s. d. 42 6 2							
The greatest number of houses are under a rental of 40*l*., their number being	162,862							
More than half the total number, or	56·5	per Cent.						

* In 1841 the return made under the census was 265,553 houses. The enumeration of houses according to the number of persons assessed, though it is not strictly accurate, appears to be a good approximation.

The gross daily quantity of water pumped into the metropolis amounts, according to the preceding returns, to upwards of 44 million gallons. In order to give a conception of the quantity of water thus delivered, it may be stated, that the daily supply would exhaust a lake equal in extent to the area of St. James's Park, 30 inches in depth; that the annual supply exceeds the total rainfall of 27 inches over the populated portion of the metropolis (25 square miles), by upwards of 50 per cent., and that it would cover an extent of area equal to that of the City (or about one square mile), with upwards of 90 feet depth of water.

The daily supply would, however, be delivered in 24 hours, by a brook 9 feet wide and 3 feet deep, running at the rate of 3 feet per second, or a little more than two miles per hour; and three sewers of 3 feet in diameter, and of a proper fall, will suffice for the removal of the same volume of refuse or soil-water.

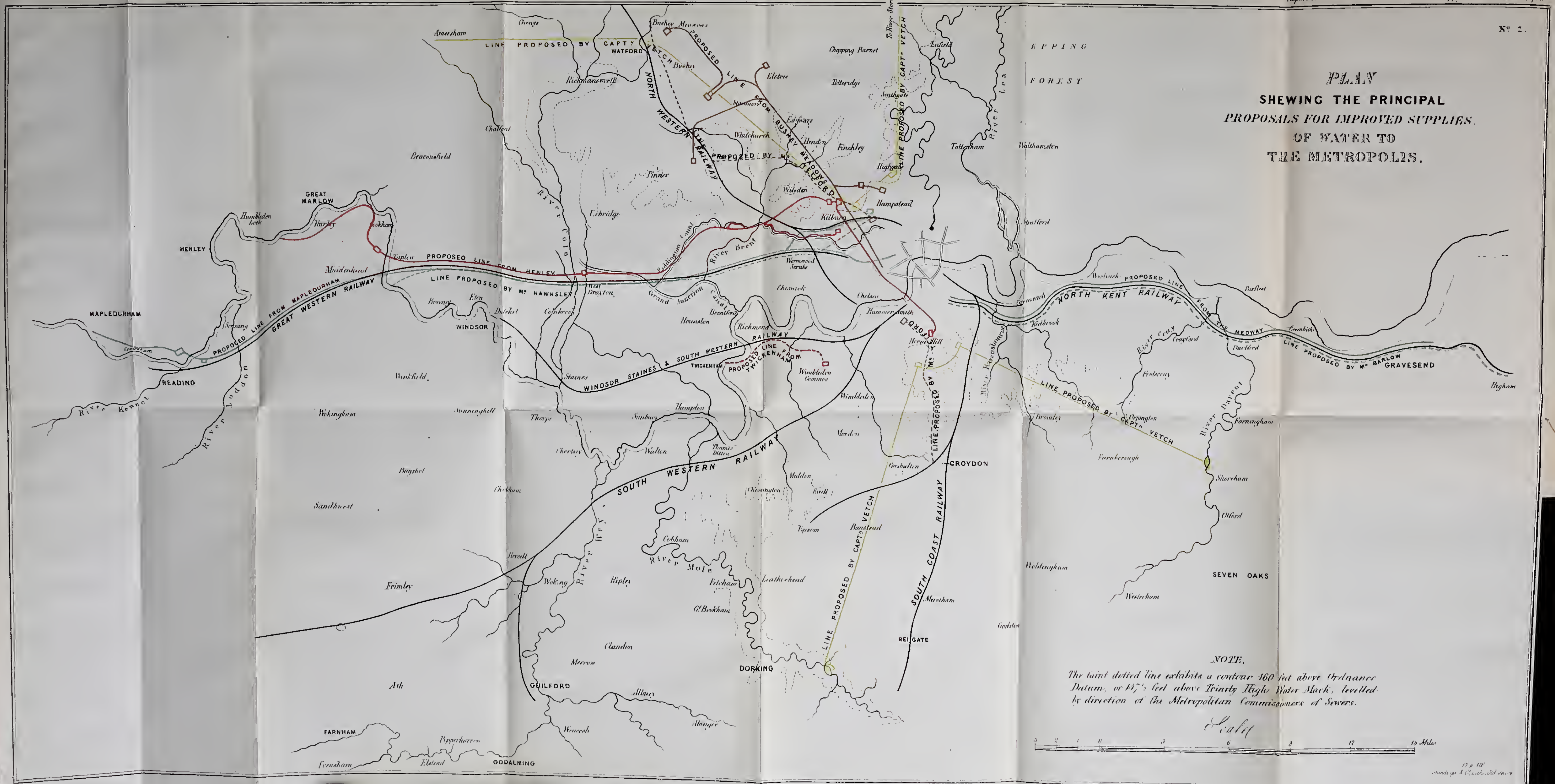
The total weight of this annual supply of water is nearly 72 million tons. The daily cost of raising the whole quantity by engine power 100 feet high, would be about 25*l.* or about 9,000*l.* per annum.

The average daily quantity pumped into the districts, exclusive of the supplies to large consumers, and of the quantity used for all public purposes, would, supposing it were equally distributed for each house, occupy about 50 pailfulls, and would weigh about 13 cwt.

The position of the works and reservoirs of the Companies and the districts severally supplied by them are shown on the annexed map.

Having thus stated the quantities of water pumped into the several districts by the existing Companies, with the sources and other particulars of their supply, we have now to submit a statement of the principal schemes which have been brought forward with the view to remedy the acknowledged evils of the present supplies.

It will be observed, from the first of the above tables, that the present pipe-water supplies of the me-


No 2.
PLAN
SHEWING THE PRINCIPAL
PROPOSALS FOR IMPROVED SUPPLIES
OF WATER TO
THE METROPOLIS.
NOTE,
The faint dotted line exhibits a contour 160 feet above Ordnance Datum, or 157½ feet above Trinity High Water Mark, levelled by direction of the Metropolitan Commissioners of Sewers.
Scale
Miles
LINE PROPOSED BY CAPTN VETCH
PROPOSED LINE FROM BUSHEY MEADOWS
PROPOSED LINE FROM HENLEY
LINE PROPOSED BY MR HAWKSLEY
PROPOSED LINE FROM MAPLEDURHAM
PROPOSED LINE FROM TWICKENHAM
PROPOSED LINE FROM THE MEDWAY
LINE PROPOSED BY MR BARLOW
GREAT WESTERN RAILWAY
NORTH WESTERN RAILWAY
SOUTH WESTERN RAILWAY
WINDSOR STAINES & SOUTH WESTERN RAILWAY
NORTH KENT RAILWAY
SOUTH COAST RAILWAY
EPPING FOREST
River Lea
River Colne
River Brent
River Kennet
River Loddon
River Wey
River Mole
River Darent
River Cray
River Ravensbourne
Paddington Canal
Grand Junction Canal
Amersham
WATFORD
Rickmansworth
Bushey
Elstree
Stanmore
Edgware
Hendon
Finchley
Highgate
Hampstead
Kilburn
Willesden
Whitchurch
Pinner
Uxbridge
Chalfont
Bracensfield
GREAT MARLOW
Hambleden Lock
Hurley
Cookham
HENLEY
Taplow
Maidenhead
West Drayton
Colnbrook
Datchet
Eton
Bovency
WINDSOR
MAPLEDURHAM
Caversham
Sonning
READING
Winkfield
Wokingham
Sunninghill
Staines
Thorpe
Chertsey
Chobham
Bagshot
Sandhurst
Frimley
Woking
Ripley
Cobham
Fetcham
Leatherhead
Gt. Bookham
Clandon
Merrow
GUILFORD
Albury
Wonersh
Ash
FARNHAM
Frensham
Elstead
GODALMING
DORKING
REIGATE
Merstham
CROYDON
Carshalton
Banstead
Epsom
Ewell
Chessington
Malden
Morden
Wimbledon
Wimbledon Common
Herne Hill
Hammersmith
Chelsea
Chiswick
Wormwood Scrubs
Brentford
Hounslow
Richmond
TWICKENHAM
Hampton
Sunbury
Walton
Thames Ditton
Tottenham
Walthamstow
Stratford
Enfield
Chipping Barnet
Totteridge
Southgate
Greenwich
Woolwich
Lewisham
Bromley
Farnborough
Orpington
Foots Cray
Crayford
Dartford
Greenhithe
Barfleet
GRAVESEND
Higham
Farningham
Shoreham
Otford
SEVEN OAKS
Westerham
Woldingham
Godstone

tropolis are derived principally from the River Thames and its tributary the Lea. These waters are essentially of the same character and quality. The chief plans which have been proposed to afford additional and better supplies, have sought them also from these same sources, or from other tributaries of the Thames of very similar quality, or differing from them in no advantageous degree. Mr. Telford proposed to introduce additional supplies from the Verulam, above Watford, on the north of the Thames, and from the Wandle, near Croydon, on the south. Mr. Robert Stephenson proposed to introduce a supply from wells to be sunk in the chalk near Watford. Mr. Rendel proposes, in a recent paper, to bring in additional supplies from the River Lea. Captain Vetch proposes to introduce the waters of the Colne, of the Lea, and other streams of that neighbourhood, on the north of the Thames, and those of the Darenth and the Mole on the south.

Of other schemes recently urged for adoption, one proposes to bring in a new supply from the Thames at Henley; another from the Thames at Maple-Durham. Mr. Hawksley proposes to bring in a supply from the Thames near Maidenhead; and there are several other plans, differing chiefly as to the part of the Thames or its tributaries of similar quality from which it is recommended to take the water, and the mode in which it is proposed to introduce it.

Mr. Barlow proposes to bring an additional supply from the chalk of the North Kent district; another scheme is to obtain it from the chalk beneath the metropolis by sinking wells; and another proposes the introduction of a supply from the Medway. The principal proposals which have been brought forward, are marked on the annexed plan No. 2. With reference to the whole of these schemes, it must be observed, that they propose to introduce the additional supplies without any essential changes in the internal distributory apparatus, excepting that four of them so far recognize the conclusions arising from recent

sanitary investigations, as to make the supply continuous instead of intermittent.

With respect to the quantities, however, the majority of these plans propose to afford supplies very considerably greater than those now given by the present Companies.

Mr. Hawksley proposes a total supply of 75 million gallons per diem.

The Henley scheme proposes a supply of 100 million gallons per diem for the public service, and 100 million gallons per diem for flushing sewers. Mr. Barlow also proposes a supply of 100 million gallons per diem. From the sources proposed by Captain Vetch, a still greater quantity may be provided, while the Medway scheme is stated to have at command three or four times this amount.

The river Lea, from which the New River Company derive a large proportion of their supplies, receives town drainage, and the water, as delivered, does not materially differ in quality from the water of the Thames taken high up the river. The disadvantages of small streams appear to be in the greater variations in quantity and quality. The obvious advantage of the larger stream is in the more regular average of quantity and quality. This and other considerations led us in the first instance to the examination of the water of the River Thames, as varied in its quality at different points by the drainage of towns. We were also led to examine to what extent its original quality was changed by the arrangements for its distribution and internal delivery; and we did so with the view originally of determining how far the adventitious arrangements might be modified for the improvement of the quality of the supplies.

For this purpose we obtained the service of Dr. Angus Smith, who had been engaged by the British Association for the Advancement of Science to report on the means of improving the supply of water to towns, and he was requested to examine the River Thames from its source; to take specimens of the

water at different points; to analyze these specimens, and to determine, as far as might be done by chemical analysis, the extent to which the river was polluted in its course by receiving the drainage of different towns.

We have further availed ourselves of the very extensive experience of Dr. Lyon Playfair, in the analysis of water for the supply of towns. We have derived important aid from Professor Way, the chemist to the Royal Agricultural Society. The special Report of Dr. Angus Smith, the Paper of Professor Clark, and the examinations of several other eminent chemists, are contained in the Appendix.

The works of the existing water Companies for the supply of the metropolis were examined *in situ* by Mr. Cresy, one of our engineering inspectors; Mr. Austin, our secretary, was charged, as an engineer, with the examination of schemes proposed for new works; Mr. Rawlinson, our engineering inspector, who has been much and specially employed in the consideration of water-works on a large scale; Mr. Lee, our inspector, who has had experience in the examination of new gathering grounds; Mr. Ranger, the inspector who has been required to consider of supplies for Croydon, Tottenham, and other towns connected with the metropolitan district; Mr. Rammell, our engineering inspector, who at Paris has examined the difficulties to be provided for in applying water for the removal of refuse by pumping, on the abolition of cesspools, were also directed to aid in the examination of some new sources of supply which were developed in a later stage of the investigation. In our researches we have received aid from Professor Ramsay, a director of the Ordnance Geological Survey, and also from Mr. R. Austen, of Chilford Manor, Surrey, a fellow of the Geological Society, who has very successfully studied the geological formation of some of the districts examined. Later on, Dr. Sutherland, our medical inspector, was directed to make as particular investigation as he could within the time as to any effects observable from changes in the qualities of water supplies on the health

and domestic comfort of the population in several northern districts where improved supplies had been given from gathering grounds.

At the opening of the investigation an array of witnesses was presented, on opposite sides, offering testimony of a most conflicting character; on the one side were consumers of water, resident chiefly in the poorer districts, complaining of the essentially bad quality of the water delivered into the metropolis by the trading Companies, and in proof of the truth of their allegations, producing specimens of dark and foul water, abounding in visible animalculæ: on the opposite side were the officers and witnesses on behalf of the Water Companies, asserting the entire untrustworthiness of the testimony on which such complaints were made, maintaining as unquestionable the purity of the water supplied by them, alleging indeed that it is of unexampled excellence, and presenting specimens with the analyses of eminent chemists.

At the first view of this conflict the impression might be entertained that there must be misrepresentation and even mendacity on the one side or the other; and as much of the opposition to the Companies evidently originated with the promoters of rival schemes, the testimony of their assailants was open to the *primâ facie* suspicion of fabrication.

Specimens, however, collected by our inspectors, and by witnesses on whose disinterestedness we could rely, presented the same differences, and the like apparent grounds for contradiction, which, on investigation, appeared to be explicable by the different points at which waters derived from the same sources were taken. The companies, or their officers, took their specimens from the water in their reservoirs, where the impurities had subsided by rest, or had been removed by filtration. The other specimens of water, derived from the same source, were taken from the butts, cisterns, or vessels, in rooms where it had stood, and where it was in the condition in which it was generally consumed by the people. Accepting and believing the respectability and

intended veracity of the directors, officers, and witnesses of the Companies, the fact that the chief causes of these extreme differences in the quality of different waters should have been unobserved or uncared for by them, opens a field of observation as to the management, which will be widened when we have occasion to submit the evidence as to the quantities of water actually supplied and the mode of its distribution We proceed to cite examples of the nature of the evidence, descriptive of the condition of the water within reach of the inhabitants of the poorer districts.

Mr. Bowie, one of the surgeons who assisted us during the recent prevalence of cholera, in his Report on the cause of cholera in Bermondsey, a district where the mortality was excessive, speaking of one particular district, called Jacob's Island, says:—

The supply was wretchedly defective, and the water very impure. I may also refer to my Report on Bermondsey; where, speaking of Jacob's Island, I mention that, "in this island may be seen at any time of the day, women dipping water with pails attached by ropes to the backs of houses, from a foul fœtid ditch, its banks coated with a compound of mud and filth, and strewed with offal and carrion; the water to be used for every purpose, culinary ones not excepted; although close to the place whence it is drawn, filth and refuse of various kinds are plentifully showered into it from the wooden privies of the wooden houses overhanging its current, or rather slow and sluggish stream; their posts or supporters rotten, decayed, and, in many instances, broken, and so little regard is paid to decency, that women may be seen entering and leaving these projecting privies, and the filth dropping into the water, by any passer by. I was also informed, that during summer, crowds of boys are to be seen bathing in the putrid ditches, where they must come in contact with abominations highly injurious."

Was much of this supply obtained from the ditches in the neighbourhood?—Yes; some water was obtained from the Vauxhall Company's supply, but it was very limited: most of the houses were supplied from these ditches and mill-streams.

You say this bad water was from the ditches, not from the company's supply?—Yes.

Dr. Milroy states—

That the people in this wretched locality do not willingly submit to this horrible grievance I can testify from my own inquiries. I shall mention one case. A decent-looking woman

assured me that it was only at the expiry of a seven years' lease last summer, when she gave notice to her landlord that she would leave the house, that he at length consented to have water laid on from the pipes of the Southwark Company. She had repeatedly applied to have it done before, expressing her willingness to pay 20*s*. or 24*s*. extra a year, but without effect. This woman, I should mention, kept a cow in a back yard that was not above six or eight feet square, for the supply of milk to the neighbourhood. Her anxiety to have the water laid on had arisen not only from regard to her own and her family's health, but from concern about that of the poor animal which provided her with the means of subsistence, for she was well aware that the water from the black ditch in front of her house could not but damage the quality of the milk.

The complaints here are of the class which come under the head of the deficiency of supply, and have, obviously, nothing to do with the quality of the company's supplies, but, apart from the quality, are referable to the subsequent questions as to the expense of the distributory apparatus, the mode of providing it, and the rates of charge and other circumstances which impede the voluntary extension of proper supplies of water to the poorer districts. One of the most severe visitations of cholera which occurred on the south side of the metropolis, where several houses were almost entirely cleared of inhabitants, that in Albion-terrace, Wandsworth-road, was marked by the circumstance, that, among other exciting causes of disease, the cesspools or drains of the houses had overflowed into the subterranean cisterns from which the inhabitants derived their supplies of water. In ordinary times, it is known that troops who have drank water polluted with animal or vegetable matter in a state of decomposition are peculiarly subjected to dysentery. At this extraordinary epidemic period, when the human organism was more than commonly depressed and susceptible; when the state of the atmosphere was sickly in the extreme, and when animal and vegetable decomposition was observed to be more than usually rapid and copious, the effects were, as might have been expected, more violent and fatal.

Whatever noxious ingredients there may be in the

common air, there is reason to believe that they are for the most part capable of being absorbed by the water aërated with it; but the direct proof of the injurious action of the impure air of large towns upon the water exposed to it, is difficult. The evidence, however, of the powerful influence of impure water in predisposing to the most violent attacks of cholera is indubitable; but in all the well-ascertained cases of this, the water had unquestionably been contaminated by the contents of cesspools, sewers, or the like having percolated into it. Throughout the country, examples such as we shall hereafter have occasion to refer to were so common, and the circumstances so marked to the popular apprehension, as to afford apparent ground for the popular belief in some places that the wells were poisoned.

Besides the positive evil of water absolutely impure, there was exhibited frequently, in such a district as that of Bermondsey, the negative evil of the want, during the prevalence of the epidemic, of water that was pure and salubrious for the drinking of the patients.

The parish of Rotherhithe suffered more severely from cholera even than Bermondsey. Mr. Grainger thus reports of it:—

It is also particularly characterized by the supply of water in many parts of it being most deplorable. Many of the poor depend for their supply on ditches which receive the Thames water; and others obtain their water from wells, which are, owing to the lowness of the district, also fed by the river.

The poor of Rotherhithe, and other places near the river, however, use the water not only in its foul state as it comes in, but after it has been contaminated by other causes. The evidence of Mr. Chandler, the medical officer of this parish, who had the superintendence of the measures adopted to meet the epidemic, and who himself saw about 600 cases of cholera and 3,000 of diarrhœa, places this evil state of things in a strong light. After the cholera had shown itself lightly for several months by isolated attacks, at the end of June there was a sudden and violent outbreak. "The disease began on the last day of June in a certain street, and in 16 houses 20 cases occurred. All these houses were supplied by one well, the water of which was derived from the Thames, and was, moreover, as it was expressly ascertained, contaminated by infiltration from a foul open ditch; several of the

persons who died were decent mechanics, and not in destitute circumstances. In another street with about 25 houses, each having on an average two families, and where the epidemic was very severe, 15 deaths at least having occurred, the water was likewise very bad, in fact it was taken out of the ditches communicating with the river, and which ditches received the matter from the privies." Mr. Chandler says in connexion with those instances, "as to the influence of bad water, his opinion is, that in some instances it decidedly acted as a predisposing cause, and tended to the spread of the disease." The Rev. G. Blick, rector of Rotherhithe and chairman of the Board of Guardians, and who rendered most valuable services to the suffering poor, says, "he was constantly occupied in aiding with the Guardians, in the preventive measures during the height of the epidemic, and observed, that in some cases when the disease had been very severe, and where the water was tainted, that on supplying pure water, and having a medical man in constant attendance, the cholera was controlled to a marvellous extent, few cases occurring subsequently. Is convinced from the facts that came to his knowledge, that the bad quality of the water in certain localities acted most prejudicially as a predisposing cause, and led to the spread of the disease."

With respect to this case of Rotherhithe, the fact of the people in the first street mentioned having been the first victims in the great outbreak, shows that they must have been highly predisposed; and as they lived in decent houses, and were in comfortable circumstances, two of the more ordinary causes of the disease, over-crowding and poverty, could not have operated. Those considerations can leave no doubt that the one main cause of the great severity of the attack was the use for domestic purposes of Thames water, further polluted by sewer matter, into which privies emptied their contents.

The evidence cited is derived chiefly from cases in which the water contained an extraordinary amount of impurity; other evidence, however, may be adduced to show the impurity as well of the distributed pipe-water as of the Thames water.

Mr. Challice, for example, a surgeon in extensive practice, who resides in Bermondsey, gives the following evidence:—

You are, I believe, a surgeon?—Yes.

Where do you reside?—In the Grange-road, Bermondsey; I am also chairman of the Bermondsey Board of Guardians, and have practised in Bermondsey for the last seven years, and largely among all classes.

You were of course called into active service during the cholera?—Yes, very much so.

Had you at the time any reason to believe that the extensive severity of the visitations of cholera in the district was influenced in any immediate degree by the supplies of water?—Yes.

Would you describe to the Commissioners the facts which led you to that conclusion?—The first fatal case of cholera that I met with was that of a master of a vessel at Gravesend. He was a fine man, in the prime of life, and in perfect health when he left London. He was going to the Baltic; he drank rather largely overnight parting with his owners and others, and he got up in the morning and drank heartily from one of the water-casks, which had just been filled with Thames water; he was soon after attacked with purging and vomiting. I went down post, and found him just dead. I asked particulars, and I found that the death was so sudden, that it almost appeared as if he had taken poison in the water; subsequently it was, from facts that came almost hourly under notice, that I formed the opinion of the direct consequences of taking impure water in producing a disordered state of the bowels, and those who had such a state of the bowels were pre-eminently in a condition to become victims to the disease.

Of course during an epidemic, when the general health is depressed, causes which have generally no perceptible effect materially affect the population. Did you perceive these causes in action at the time you mention peculiarly?—Yes, undoubtedly; there was the case of a man who lived in the Coburg-road, in Camberwell parish, in a semi-detached house, in a healthy situation, and with a garden behind the premises; his wife had noticed that the water supplied to them was exceedingly bad, and, having been informed that it was likely to affect the health of her family, she invariably boiled and filtered it: all kept in perfect health except the father, who objected to drink this water, from its being flat and unaërated; he would still drink it as it came from the water-butt, and the consequence was that he was attacked with choleraic-diarrhœa: he afterwards drank no more of it, and got well.

Then you consider this to be a fair example of the effects of using such water at such a time?—Yes; and I found that where deep-spring water alone was used, where such water was free from the effect of percolation from the drainage, persons escaped the cholera altogether.

Are not the water-butts and other receptacles often placed near the privies?—Yes, very generally.

Would not that alone be likely to contaminate water that might be pure at its source?—Yes, certainly; but here it came in with animalculæ in it.

But you think that the plan of receiving it in butts is bad?—

Yes; the purest water under such circumstances would soon become impure, and a source of disease.

Have you observed the state of these water-butts?—Yes; very frequently.

Will you describe their appearance?—Generally speaking the wood becomes decomposed and covered with fungi; and, indeed, I can best describe their condition by terming them filthy. The poor people will not cleanse them; and if you look to their cooking utensils you will likewise see a quantity of dirt deposited.

Do you think that the deep-spring waters are free from animal impregnations?—I do; and, if used, would undoubtedly very materially diminish the extent of mortality: indeed, I entertain a very strong conviction that the general use of deep-spring water for human consumption would be of the greatest public benefit. During the prevalence of cholera, I repeat, in my own practice and experience it was the most powerful preservative against the epidemic.

Mr. John Thomas Cooper, the eminent practical chemist, who resides in Blackfriars-road, was asked—

Have you observed any instances of the contamination of water by its retention in tanks, cisterns, and butts?—I know of many instances; some in my own premises, and others in those of my friends, where the Thames water with which they are supplied has, in my cisterns and in theirs, become unfit for use, and the supply-pipes occasionally been stopped up, by decaying or decayed confervæ.

Do you think that contaminations may take place to such an extent as to prove injurious to health?—If the imbibition into the human system of decaying vegetable or animal matter be injurious to health, which I believe is agreed on all hands to be the case, it must follow as a consequence that, if water becomes in any degree contaminated by putrescent matter from any cause whatever, that in proportion as the amount of decaying matter of either kind may be increased, so will the insalubrity of the water be increased also.

What is your observation of the company's water which you receive at your own residence?—It frequently comes in tainted with the smell of decaying animal or vegetable matter; it having, in fact, a slightly putrescent smell and taste.

Is it delivered filtered, or free from matter in suspension?—It comes in much clearer than it used to do, and deposits very little matter in the bottoms of the vessels in which it is detained. I think it more likely that it is cleared by subsidence than by filtration.

Do you filter the water you use?—Yes; we filter all the water we use for culinary purposes.

Are we to understand then that the smell you speak of is perceptible even after filtration?—Yes.

It is perhaps superfluous to ask you, as a chemist, whether you consider that this is a water which ought to be supplied to a population?—I certainly think not.

What description of filter do you use?—One made of finely-powdered glass, and animal charcoal; one stratum of about half an inch thickness of finely-powdered glass, upon which is a layer of about an inch and a half of well-burnt animal charcoal, and over this about three-quarters of an inch to an inch of more coarsely pounded glass, and over that the usual sponge for filters. This, I conceive, is a mechanical as well as a chemical filter.

How does it act?—Very well.

But it does not yet detain the matter in solution to which you attribute the disagreeable smell?—No; but I believe it diminishes it.

He had been previously asked—

Besides the chemical analysis of water, have you attended to the amount of organic matter contained in it in different instances?—The amount in weight of organic matter contained at any time in any natural water is always very small, but, in my estimation, is not on that account to be disregarded; it is notorious that filtered Thames water, when taken on board ship, in a short time becomes putrid and unfit for use; this is only to be attributed to the presence of organic matter originally existing in the water re-acting on the sulphate of lime, or any other sulphate it may contain, thereby engendering the production of sulphuretted hydrogen; then, as soon as the whole of the organic matter has become decomposed, the sulphuretted hydrogen partly escapes into the atmosphere by the exposure of the water to its influence, and any that may remain in the water becomes in the course of time, by the absorption of atmospheric oxygen, sufficiently oxidized as not to be distinguished. While on this subject, I may relate a circumstance that occurred about two years since in my own laboratory. I have a still that is used for no other purpose than distilling water; the accumulated bottoms of a number of distillations were accidentally suffered to boil to dryness, and become subsequently heated to that extent that decomposition of them was effected; the stench produced by the decomposition of the organic matter was peculiar, and not to be mistaken as that resulting from animal produce, and so persistent was it as to infect the produce of many subsequent distillations, although every care was taken to cleanse the still and its appurtenances almost immediately after the occurrence.

We find that previously to the approach of the cholera the Lambeth Company had applied for an

Act to authorize them to extend their works. In the evidence which the Company adduced before the inspectors appointed to inquire into the grounds of this application, is found that of Mr. R. Phillips, the chemist of the Geological Survey, of which the following is an extract:—

I believe you are a chemist?—I am.

I believe you had some water brought to you by Mr. Lynde which was stated to have been from different parts of the River Thames. Now, I will first call your attention to the water taken at Belvidere Wharf, the second specimen that was brought to you?—That was not taken from the Belvidere Wharf; that was taken from the mains near the Obelisk.

Have you submitted that water to chemical examination?—I have, to a certain extent, not so minutely as I did the others.

Did you compare the two samples of water that were shown to you, the one being from St. George's Obelisk, and the other from Thames Ditton, with respect to their becoming clear by standing?—I did.

What was the result?—That the water that I first took, that which was brought from Thames Ditton, became clear by standing.

How long would it take for the water taken from St. George's Obelisk to become clear by standing?—It has not become clear.

(*Mr. Cooke.*) About how long ago was it?—Four or five days ago.

And up to this time it is not clear?—Up to this morning.

Do you consider that the water from Thames Ditton is of a very improved quality, as compared with that obtained at St. George's Obelisk?—The quantity of water is not very great, but there is something in the one which is not present in the other, and therefore that water is not so pleasant.

Is there anything in the character of the solid mass left by evaporation in the one more deleterious than that in the other?—I do not know that it is more deleterious, but it appears to me that there was more organic matter in the one than in the other, and it was probably that, that prevented it from becoming clear. Putrefaction is much more likely to occur where such matter is present than where there is none.

Would that matter be carried off by evaporation?—No, it remains; and I found that the residue was more coloured than the first, showing that there was more organic matter in it.

Would that organic matter be removed by filtration?—I think it is possible that it might, but I cannot speak positively on that subject. I think it might, but by subsidence not.

In that case, the two waters after filtration would be on an equality?—I think it might be so. There would be some dis-

solved however, which filtration would not take out, for a part of it I take to be floating, occasioning a turbid appearance, but a quantity might be dissolved without giving the water that appearance.

Is any of this held in solution, or is it all in suspension?—Some is in suspension and some in solution.

That which is held in solution would not be removed by filtration?—Certainly not.

Have you any reason to suppose that the difference was greater in the one than the other?—I should think it was greater in that in which it did not become clear, because the residue was of a darker colour. The residue obtained by evaporation was of a darker colour, owing to the organic matter.

Is it your opinion that the water which you first obtained, that is to say, the water obtained out of the pipes of the company, as at present supplied, might be made good water for all purposes of filtration?—I cannot speak positively to that. I think it is extremely probable that it might, but not by subsidence.

(*Mr. Cooke.*) Was that water which came to you, in a fit state for domestic purposes?—It was fit for many uses, but it would not be pleasant for drinking.

Was it fit for washing purposes?—Yes. I should think so.

(*Mr. Cubitt.*) You say that filtration might, by possibility, remove it?—Yes, but it appears that the water has been filtered, and it has not removed it. I was not aware that it had been filtered.

If that which is held in suspension or in solution imparts a bad odour, would the filter get rid of that?—It might get rid of the cause of it, but the water would smell afterwards. That is my opinion.

(*Mr. Cooke.*) You think there is a superiority in the second sample you spoke of over the first, upon grounds independent altogether of the quantity of deposit or of the degrees of hardness?—The essential difference consists in the power which the one has of becoming clear by standing, which the other has not, and that which does not become clear would soon of course become putrid.

And you think the other water is not good for domestic purposes?—I have not said that I do not think it so good, for the reasons I have stated; it would, certainly, answer most domestic purposes, but for drinking it would not be so pleasant because it does not become clear by standing.

Now this particular Company was by its Act bound to filter the water delivered by it to the consumers: we are of opinion, that if its works can be denominated

filters, they are of little or no value for the effect produced.

The following are examples of the statements made to us in relation either to the qualities or the deficiencies of the water supply. In relation to the ravages of the cholera in the south-eastern districts, Dr. H. Gavin is asked :—

During your experience of the recent epidemic could you trace the effects of using foul water?—The connexion between foul drinking-water and cholera was established by irrefragible evidence. The cases where the connexion was most clear were where the parties had been recently drinking water taken from pumps near to, and contaminated by the matter of cesspools: but wherever the water was contaminated so as to be nauseous, diarrhœa was invariably present, and affected every person in the habit of drinking such water. I am not aware of any valid exceptions to this law. The most aggravated instance of foul water developing cholera was where a thirsty navigator drank of the Hackney-brook (a common sewer), and was almost immediately attacked with cholera, and subsequently speedily died. The cases next most marked were those of the 11 persons, out of 22 in number, whom I have already recorded as having perished in a certain square consisting only of a few houses, where the water was contaminated with cesspool matter. A similar story I have related with reference to the first outbreak of cholera at Fulham. In Hackney I have shown how that, out of 85 inhabitants of one locality who drank of water contaminated with cesspool matter, every one had had or then had more or less diarrhœa, and, that to avoid its excessive filthiness, the whole of the inhabitants of that row were compelled to drink and use for domestic purposes the water which ran down the kennel. These are the more marked instances, but the cases where foul water led to the development of cholera were so numerous, that all the visitors under my superintendence united in their testimony as to the influence of such water in the development of the disease. I have traced in many instances the unsuspected cause of the development of cholera in the state of the drinking-water. When it is recollected that the water of the poor is nearly always exposed to the noxious gases and agencies, which arise from privies, and the slow decomposition of the refuse in their yards, and also from those in their close, offensive, and impure dwellings, it will at once be understood that such water produced much and severe diarrhœa during the period of cholera.

In Whitecross-place, for instance, referred to in my Report on Shoreditch, there are five stories to some of the houses, each room containing a family. The deaths took place in the very top story,

which showed much more uncleanness than the lower rooms. In these upper rooms the inhabitants used the water over and over again, until it became very offensive, and "past using." The drinking-water is stated by the visitor to have been horribly offensive. The poor man, a shoemaker, and his wife, stated, a few days before their deaths, that they had not tasted a drop of water fit to drink since they had been in that house. Besides the results just referred to, the foulness of the water, acquired by exposure to a close and offensive atmosphere, renders it particularly odious to the poor as a common beverage. The water, often very much loaded with sedimentary matter, and, subsequently, rendered offensive, becomes unpalatable to the poor, who have no means of filtration.

The following is an extract from the Report of Dr. Milroy on the state of the water supply, chiefly of the poorer classes in the western districts of the metropolis :—

Among the most serious evils attending the present system of intermittent supply of water to the dwellings of the poor, is the filthy and polluted state alike of the cisterns and butts into which it is received, and of the vessels in which it is generally kept. Whether the cistern or butt be in or out of doors, it is usually uncovered, and, consequently, exposed to all the dust and smut that are continually flying about even in the cleanest parts of a large city. But this is far from being the only or the worst source of impurity to which it is liable. Not unfrequently, there is no tap at all, and often this is so inconveniently placed that it is scarcely possible to make use of it. Hence the common practice among the inmates of the house is to dip their vessels—no matter of what sort, and whether clean or otherwise—right into the cistern or butt every time that they require to draw water. Nay, I have heard more than one person say, that they have seen people actually rinsing chamber pots in the water which their neighbours drank and used for cooking. Of course, this was when the cistern or butt stood in some dark place where they were not likely to be seen. But it seems, that when the cistern is outside of the house, it is liable to the same horrible pollution from the common practice of parties who live in the upper rooms emptying everything out of their windows into the court behind, the cistern being usually placed there between the ashpit and the privy.

So disgusted are the inmates themselves of even the poorest dwellings with the water in their butts or cisterns, that very frequently they will use it only for the purpose of washing, and, unless they can catch the water directly from the pipe when it is *on*, they are obliged either to beg it from some neighbour, or (as is frequently the case) get it from the public house where they

deal. This appears to be of very common occurrence indeed, even in some tolerably decent localities, and must be admitted to be a flagrant injustice, inasmuch as they are charged indirectly in their rent for what they have little or no benefit from.

A respectable woman living in Rose-street, Covent-garden, told me that, during the whole four years she had lived in the house where she now resides, she had never once been able to use the water from the cistern even for boiling potatoes, far less for making tea, unless she happened to catch it directly from the pipe as it came in. Nor will any one who has examined this cistern be surprised at the woman's statement. Besides the ordinary sources of pollution from the dust and smut in the atmosphere, and from slops thrown out of the top windows, this cistern is resorted to by boys in the street, the house door being always open during the day, to wash their hands, and to play all sorts of pranks; such as dipping sprats, when they are in season; drowning mice, &c. &c., in it. Yet this woman paid 4*s.* a-week, or upwards of 10*l.* per annum, for her one room. But things are still worse in other places; for the water butts or cisterns are sometimes so situated, that it is scarcely practicable to reach them even for water for the purposes of washing, while it is next to impossible to catch the water directly from the pipe as it comes in. Such is the case with many of the wretched houses in that most filthy street, King-street, St. Giles, one of the very worst localities in London, where numerous deaths from cholera occurred, and where, consequently, there is the more urgent need for a most liberal supply of water. The water butts are in the cellars underneath, close to open gratings, and are therefore ready to receive whatever may be swept down from the street. The stairs leading to these cellars are so dark, that you have to grope your way down with your hands and feet, and the risk of accident is not a little increased by one or more of the steps being often broken or altogether wanting. On reaching the bottom, you are immedediately assailed by the most intolerable stench; and if you venture to go farther in towards the opposite corner of the cellar where the water-butt stands, the chances are that you sink ankle-deep in an abominable slush or quagmire. Of course, you cannot move a step without the aid of a candle, this horrible place being quite dark even in broad daylight. It appears from the statements of the inmates of the houses, that the drains gave way and burst into the cellars a few months ago, and that they have continued to disgorge their fœtid contents into them ever since, without anything having been done all the while by the landlords to abate the nuisance. But even before the bursting of the drain, the place was generally in the most disgusting condition from the privy being there, and from the floor being covered with excrement and urine. Yet the poor tenants have no other alternative, but either to go into such a horrible place as I have now described,

or to be indebted to the neighbouring publican for their daily supply of one of the prime necessaries of life. This is certainly a dreadful state of things to contemplate, and in the very heart, too, of the metropolis of this great nation. Surely, it but requires the fact to be made generally known, to convince all of the urgent necessity of a Government surveillance of the dwellings of the poor. It is utterly hopeless to expect the correction of such monstrous evils in any other way.

The serious loss of time to the poor by their being obliged to be on the look out for the exact time when the water comes on once in the 24 or 48 hours, and the not inconsiderable labour incurred by dragging their pitchers, &c., up to their rooms, are, in themselves, great objections to the present system. If the mother of the family be out of the way when the water is *on*, or ailing, so that she cannot go for it, she and her family must then be indebted to the kindness of a neighbour, or they must apply to the public house for their necessary supply.

The vessels, too, in which the water is usually kept in the rooms of the poor, are most unsuitable for the purpose, not to mention pails, old fish-kettles, and casks that leak, and thus keep the floor continually damp. The brown earthen-ware, narrow-necked and small-mouthed cans, which are most in vogue, are obviously very objectionable, from the difficulty of keeping the inside of them clean and free from the deposit which is continually taking place from the water of all the metropolitan companies.

It is worthy of notice, that during the last eight or ten months the water has, in very many parts of London, been *on* once in 24 hours, instead of every second day (or three times a-week) as it was formerly. Of course, this daily supply is an advantage; but as I do not understand that any extra charge has been made, the question naturally occurs how comes it that it has ever been otherwise, or that it is not universally the case all over London? The circumstance of its being now done without additional expense, is a proof that injustice has been inflicted on the public hitherto, and that a much more plentiful supply might have been furnished by the water companies, than has yet been the case.

Sometimes the poor are liable to have their water supply cut off by their landlord, when he finds that he can sink a well at little expense in the neigbourhood, to which they must then resort for what they require. This is about to be the case with five houses in Evans' Buildings, Chelsea; the inmates complained to me of the injustice and hardship of this proceeding. The well, I should mention, has been sunk in a back-yard close to a large stable, and in the immediate vicinity of a dung-pit that was in use a few years ago. The reason alleged by the landlord, is the expense to which he has been put by the wilful injury of the water-pipes, butts, &c., either by the residents themselves or by unknown persons without. That there is truth in this statement, was obvious

from the exposed part of the lead pipe having been cut across and stolen in more than one of the houses. But would not this very mischief be, in a great measure prevented, if the water was continually *on* in the pipe, and therefore, without the necessity for any butt or cistern out of doors?

From all that I have seen of the exceeding hardships to which the poor are obliged to submit in the matter of water supply, and still more from the remarks which I have heard them make upon the subjeet themselves, I am convinced that no greater boon could be conferred upon them, or one whieh is more calculated to do immediate good, and to prepare the way for further improvements in their physieal condition, than the substitution of a *continuous* for the present vicious system of occasional and *intermittent* supply, with its necessary, but most objectionable adjunets of impure butts, cisterns, and other reeeptaeles for the detention of the water. To do justice to the poor water should be laid on to each floor of each house.

Mr. Bowie thus describes the condition in which he found the water supply to the poorer classes in the city of London in ordinary times:—

Were you not directed to make speeial inquiries on the part of the Metropolitan Sanitary Commission as to the supply of water in the city of London? Will you explain in what state you found it?—In general very seanty, and sometimes altogether wanting. The water often thick, muddy, diseoloured, putrid, and unfit for drinking or culinary purposes. I would instance as proofs of this statement, out of a host of others, the houses in Fireball-eourt, Three Pigeon-eourt, Cock-and-Hoop-court, Seven-Step-alley, Houndsditch; Crown-court, Seething-lane; Barking-churehyard; Rose-lane, Tower-street; Pewterers'-buildings, Cannon-street; Printing-house-square, Coleman-street; Saddler's-place, London-wall; Ivy-lane, Newgate-street; Mac's-place, Greystoke-plaee, Fetter-lane: all in the city, where the inhabitants thus express themselves, that "The time the water was on was too short, the fatigue of carrying it up stairs very oppressive, and much time lost in proeuring it." "There was no water laid on." "Water was got where they could, by begging, borrowing, and from the neighbouring pumps." "They have been without water for eight years, and often more in need of it than victuals." "They have been without water for nine years." "The water is dipped with pails, and is often very dirty." "The water, instead of being clear and fit to drink, often looks quite yellow." "The water in the eistern is only fit to rinse a pail or cleanse the privy, as every impurity gets into it. It has even been used for drowning kittens. Two open tubs stand behind the door of the kitchen as water-butts, and have only been cleansed out once in the nine years." "The water (supplied from a pump) is shockingly bad, tasting as

if they were drinking something putrified, and often containing live worms more than an inch long, supposed to be from the burying-ground at the back of the house." In addition to this, a gully-hole is in close connexion with the pump, by which foul water may find its way into the well.

This description was fully confirmed by a careful house-to-house examination, made in the courts and alleys within the jurisdiction of the Corporation of the city of London, by Mr. Toynbee.

Dr. H. Gavin was examined, in relation to the condition in which he found the supplies furnished to the poorer population in the eastern districts of London:—

What proportion of the people you visited during the house-to-house visitation were supplied by stand-pipes ?—In Hackney about half the houses are supplied by stand-pipes; in Bethnal-green, with very few exceptions, the dwellings of the poor are supplied with water by means of stand-pipes; in Shoreditch, a larger number of houses have water laid on, but still the number of dwellings supplied by stand-pipes is very considerable. In a few instances some squares or rows of houses, as Thorold-square, Bethnal-green-road, the Oval, Hackney-road, the Crescent, Union-street, Kingsland-road, have such reservoirs communicating with the main, which by means of a pump supply water constantly to the inhabitants. With these exceptions all poorer and middle-class dwellings in Hackney, Bethnal-green, and Shoreditch are supplied as I have mentioned. The poor preserve the water, either 1st, in butts—cisterns are almost unknown (I only met with two attached to the dwellings of the poor and middle classes in Bethnal-green, the one was a large covered butt, the other an open wooden cistern containing the remains of cooked fish), or 2nd, in small tubs, or earthenware jugs, pans, or sometimes in small crockery-ware bowls, and sometimes soup-plates. Water preserved in such tubs or pans is nearly always taken in-doors. Such vessels are never covered. Even where there are small butts, the water is still preserved in-doors in small open vessels; when there are tubs, the tubs are very frequently stowed away below the beds. In one instance a child fell into one of these tubs, which projected from below the bed, and was drowned.

Then it is incident to this plan for having water from stand-pipes that the people keep the water in their rooms ?—Yes; even where there are butts, they are so small that the people attempt to increase their store of water by preserving some in open vessels in their rooms; in all other cases it is the nearly invariable practice of the poor to preserve their water for drinking and cooking *in their rooms.*

What is the effect of the retention of water in close atmospheres?

—In some places I have found the water used for drinking and cooking almost putrid, even where it had stood for a short time only; in nearly every place, whenever the water has been retained for a day, it has become offensive to the taste. When the water is preserved outside of the house, it is always retained in open vessels; the butt is generally situate close to the privy, sometimes under the same roof; the water is therefore always exposed to the impurities floating in and liable to be deposited from the atmosphere, and always liable to be contaminated by the absorption of foul and malarious air arising from the privies and the back yards saturated with the debris and decomposing matters. When water is taken into the close, heated, and offensive rooms of the poor, it rapidly absorbs the offensive gases, &c., and becomes tainted; and when the water has been preserved some time in butts or tubs outside, exposed to the fœtid atmosphere of a privy, it taints still more rapidly. It is almost impossible, on calling for a tumbler of water in the houses of the poor, to find it free from a mawkish taste. As an example of the mode of supply by butts, I may refer to Beckford-row, Bethnal-green. The butt, 21 inches in diameter by 12 inches deep, is under the same shed as the privy. It supplies water to Beckford-row and Alfred-row; the former consists of 16 3-roomed houses, each having a separate family. The latter row is the southern half of Beckford-row; the water supply to the occupants of these 48 rooms consists thus of about as much as would subserve to the wants of one individual. When it is considered that the supply is intermittent and thrice weekly, the deficiency in the storage for water under the intermittent system may be estimated. A particularly objectionable manner of storing water consists in retaining it in small butts or tubs, wholly or half sunk in the ground. This mode prevents the butts or tubs from being cleansed, and the sediment which collects from being removed. Water retained in such receptacles is of a mawkish, earthy taste. This mode of preserving water is common to several of the places called "gardens" in Bethnal-green. It follows, from the total want of external means of storing water, and from the small size of the existing receptacles, that the poor are compelled to preserve their water in small vessels, and, as a rule, in their own rooms.

It is in answer to such descriptions of the common supplies of water, that we have had presented, on behalf of the companies, specimens of water taken from their reservoirs, and chemists' analyses of them.

These specimens, impartially considered, are usually but second rate, nevertheless it has been deemed important to endeavour to distinguish the qualities that are essential or natural, from those that are adventitious, to

the chief sources of supply. This endeavour was made originally with the view to ascertain whether the impurities might be prevented or removed, and at what expense. To persons who go up the River Thames in fine weather, the additions of matters in suspension, if not in chemical combination, are apparent to the sight. High up the river, the water, in fine weather, is so transparent, that the bottom is visible more than eight feet deep. As the examiner proceeds downwards, the transparency diminishes, and the water becomes turbid until it reaches the metropolis, where nothing is to be seen within a few inches beneath the surface. It was the task of Dr. Angus Smith to follow the course of the river, and to examine and by analysis ascertain more closely than had hitherto been done, the nature and proportionate quantities of these visible additions. This he has done carefully, with all the aid which chemistry in its present state is capable of affording. But as yet chemistry has failed to determine the qualities of much animal and vegetable, and above all gaseous matter, that is perceptible and offensive both to the taste and to the smell.

The clear water taken up above Richmond is not disagreeable to the taste. After it has stood for a time in such a position as the reservoir in the Green Park, exposed to the air of the metropolis, it loses its briskness and becomes comparatively vapid. After it has stood for a time in a butt in a close court, near a dustbin or a privy, even after filtration, a change becomes perceptible to the smell, which chemical analysis does not follow. After it has stood for a time in a close room, under such circumstances as the witnesses cited have described, it becomes positively fetid, and effects are produced from drinking it which are not accounted for by any quantitative analysis. These effects are probably to be ascribed to the absorption by the water of noxious matters held in suspension in the air, but chemistry has not yet, by analysis of the common air, detected the most potent causes that affect injuriously the public health. The following

questions upon this topic were put to Mr. Hoffman, the Professor of the Royal College of Chemistry :—

In respect to the quality of the air of the atmosphere itself, it is observed that a child taken from a mountain district in the country, and placed in a close court or alley in a densely-peopled town district, will lose its healthy colour, and no longer thrive at the same rate, although its condition in other respects may remain the same. Is not this a test of the difference between one atmosphere and another as decisive as litmus paper for an acid or alkaline solution?

Has chemistry been able to determine the agencies in local atmospheres which produce such effects as are thus universally experienced in the young, susceptible, feeble, and sickly?

It cannot be denied that the air in the close courts and alleys in a densely-peopled town district produces effects upon the organism which are not observed, *e. g.*, in a mountainous country. These effects may, to a very considerable extent, be due to the difference in the physical and mechanical condition, state of motion, rapidity of change, &c., of the two kinds of air in question ; nevertheless, part of these effects must, I believe, be ascribed to the presence of certain constituents which the air contains, in addition to its usual components. These constituents must be present, however, in exceedingly small quantity, for chemistry has not, up to the present moment, succeeded in isolating these substances, or characterizing them by particular re-actions. As yet, in the air only, the presence of oxygen, nitrogen, aqueous vapour, carbonic acid, and ammonia, has been accurately established, but it has been proved that occasionally other substances must exist in the atmosphere ; for, on passing the air of certain localities through concentrated sulphuric acid, the acid is found to have become black, an effect which is not produced by any of the constituents mentioned above. Thus the presence of substances other than those enumerated is indicated only by their action upon the organism and upon sulphuric acid, but we are unable to say whether both kinds of atmospheric constituents are the same.

You must have had experience of a London fog : has chemistry the power of analyzing its constituents?—The experiment has never been tried ; but, although I think that it would not be difficult to condense aqueous vapour, and to collect finely-divided carbon, and various products of the combustion of coal from a London fog, on submitting a sufficient quantity of the foggy air to analysis, I am not prepared to say whether there are not at such periods minute quantities of certain constituents in the atmosphere, for the detection of which science is not sufficiently advanced, and which, in this respect, would resemble the additional air constituents supposed to exist in densely-peopled cities.

Since it is a matter of common experience that water absorbs a quantity of the air which sweeps over it, or in which it is confined, it would follow that it may absorb matter of which chemistry has not yet determined the essential properties?—Most of the gases having been found to dissolve to a certain extent in water, it is very probable that the atmospheric constituents referred to are likewise soluble in water. This question, however, cannot be positively decided as long as we have not become more fully acquainted with the nature of these substances.

He states that 1000 gallons of water dissolve, at the common temperature, 25 gallons of nitrogen to 6 gallons of oxygen, 1000 gallons of carbonic acid 500,000 gallons of ammonia, the gas, it may be observed, which escapes so largely (and for agriculture so wastefully) from the dung and refuse filth retained in the close courts and bye places in the ill-cleansed districts of the towns; the gas, under these circumstances, always carrying with it vegetable or animal matters in a high state of putrescency.

Dr. Lyon Playfair thus varies the illustration of the important fact as to the effects of aëration upon the original chemical qualities of waters:—

Then that which has not yet by analysis been found by chemists will yet govern the quality of the air or of water?—So strong is my impression on this point, that in the midst of the cholera I urged it on the Board to warn the public against keeping water in the house, which, though at first entirely pure, would, if kept in cisterns, absorb the vitiated air, and this would find its way, in a concentrated form, into the system of those who drank the water. In consequence of that recommendation the public were recommended to use boiled water, but that should be used at once, as it is more absorptive than water unboiled. The Chinese are well aware of the value of boiling water containing organic impurities. They are accustomed to use boiled water for the purposes of drinking. A temperature of 212 degrees, that being the boiling point, is sufficient to destroy decay, so that boiled water loses the injurious influences due to the decaying matter which may be present.

Then the absorption of the air by water kept in cisterns or close rooms would be very considerable, and the taste of the water would be very likely to be altered?—Yes.

Have you any doubt that water exposed to an impure and noxious atmosphere is capable of absorbing noxious and impure matters, and thus proving injurious to the health?—I have no doubt of it; in fact, there is too ample experience in proof of it.

What sort of precautions did you recommend at the time of the cholera with respect to water?—I thought the most effective means of avoiding injurious results would be to boil the water, if it were immediately used on cooling. It should be allowed to cool in a close vessel, because boiled water is more absorptive of all gaseous malaria than unboiled water. It is also advisable, though it does not remove danger to the full extent, to filter the water through charcoal, which removes a large proportion of the organic inpurities.

Of course at that time, knowing the effect of this absorption, you were alarmed at it?—I was; and I may mention one example of how water absorbs gaseous impurities. One of my assistants was making experiments with an oil, which had the smell of the concentrated urine of a male cat. The smell was insufferably offensive, and was so readily absorbed that it was impossible to drink the water placed in the room; and our clothes, especially the hair, were saturated with the smell, which did not disappear for several days. Every vessel containing a liquid in the room soon became contaminated with this horrible smell.

The particular attention of Dr. Angus Smith was directed to the investigation of the known influence of vitiated air on water, and the results are stated in his Report. He found traces of ammonia in the rain which had fallen in Manchester. But chemical evidence has yet yielded no farther results on this topic than those indicated by the two eminent professors whose evidence we have above cited.

It stands, then, upon the evidence of common observation, and upon the testimony of the senses of taste and smell, that waters of the same source and composed of the same chemical constituents may be largely varied in quality by exposure to different atmospheres; and it rests upon the evidence of medical observation, that impure water taken into the stomach occasionally produces more sudden and violent effects than impure air introduced into the system by the respiratory apparatus. This may depend in part on the physiological fact that water taken into the stomach passes directly into the blood by venous absorption; it being one of the distinguishing characters of venous absorption that it makes no selection, but admits at once whatever is presented to the imbibing veins; and in part also on the fact that water being capable of holding in solution a greater

amount of foreign matter than air, noxious matter may accumulate in water to a greater extent than in air. It may be stated as an aphorism, that they who drink water which has stood for a time, or been exposed in a town, drink town air, whilst they who drink water brought direct from an elevated rural district, without exposure, are drinking country air. The dependence of water on aëration for its most important quality, appears from Hippocrates to have been matter of early observation. He notices that when an observer entered a strange city, if he informed himself well as to the air, the water, and the locality, he could not miss knowing either the diseases peculiar to the place, or the particular nature of the common diseases; and might tell what epidemics would attack the city either in summer or winter, and what each individual will be in danger of experiencing from the change of regimen. He appears to have considered the qualities of water, for the supply of a population, as dependent upon the aspect of its source, as well as upon its elevation.

On one important point, however, the evidence of the senses, in respect to the qualities of water, is deceptive. The senses are greatly misled by temperature, especially by coolness and clearness—coolness giving the sensation of freshness; reducing bad odours, and concealing bad tastes. Widely-spread evidence has been presented of the continuous use of shallow spring waters in the metropolis, which from their site must be, and which are proved to be, polluted with the drainage of cesspools or grave-yards. It is only when the pollution has been larger than ordinary, and has excited suspicion by the colour of the water, and when the water has been allowed to stand, or when the temperature has been accidentally raised, that distrust has been created. Our officers who have gained experience in trying waters for the supply of towns, have found it necessary, in aiding the judgment by the taste, to take the precaution of previously elevating the temperature of the water tried.

By an elevation of the temperature—the purest water, distilled water indeed, may be made revolting

to the stomach. In medicine, warm water is commonly administered to aid the action of an emetic.

The disregard of arrangements for securing coolness in the water delivered, the neglect of the powerful effects upon its quality of exposure to polluted atmospheres, and the apparent unconsciousness of the operation of such influences upon the quality of the water supplied by the leading Companies, may be adduced as facts decisive of the character of their management, and not less so of the new leading schemes of water supply, in which these qualities, as influencing the public health, are equally unnoticed or disregarded.

Of the water conveyed for the supply of a town, the quantity actually used for drinking is so small in proportion to the entire bulk, that it has been objected that, economically, it is not worth while to incur the expense of preparing the whole bulk for that purpose. Considering the social as well as sanitary importance of a perfectly wholesome quality of water, we can by no means accede to this the common view of water Companies, and of many of their engineers. But evidence is given that the quality of coolness is found to be of so much value, as to induce brewers and other large consumers to incur considerable expense to obtain it. Thus a majority of the larger brewers in the metropolis, have incurred considerable expense in sinking very deep or what are called artesian wells to secure water, when they might obtain supplies of Thames water. Mr. F. Braithwaite, the engineer who has sunk a large proportion of the deep wells near London, was asked—

It appears that the brewers, who can avoid it, never use the Thames water?—My opinion is that the preference shown to well water is on account of its temperature, varying, summer and winter, from 52° to 54° only; which enables the brewers (being able to refrigerate the worts) to brew all the year round, with a large economy in hops.

Then you think it is temperature, rather than quality, that the porter brewer requires in the water?—Confining the question to well and river water, I think it is: for I do not consider there is any material difference in the quality; it is true that the well-water is more filtered.

What would be the expense of one or more of these larger deep wells?—

	Messrs. Reid's cost . . .	£7,000
	Blackwall Railway . . .	8,000
Published	New River	12,400
	Hanbury's	5,795

It is difficult to state the cost of many of the deep wells in London; it may be said that many of them, more or less, have been a continued source of expense and trouble to the proprietors. The expense varies, for some of the wells have distinct engine-power, and some are worked by the engine of the establishment doing the general work.

For the supply of steam-engines with condensing water, the power and value of water may be measured by the thermometer, according to the degree of heat.

For sanitary purposes, also, the quality of coolness is of very great importance, particularly with reference to the reception and removal of refuse, cold impeding and even arresting decomposition.

Other instances may be given of the crude state of the present system of distribution in which equally important points are neglected; and of the new cases in the administration of supplies of water on a large scale, for which it is requisite to provide.

Dr. Angus Smith was requested, in his instructions for tracing the changes of the Thames water from adventitious pollutions, to aid his chemical analyses by microscopical examinations of the animalculæ contained in it. The view with which these instructions were given was to ascertain whether, on the point most important for sanitary purposes, not merely the quantity, but the nature and quality of organic matter contained in water, which chemical analysis leaves obscure, some light might not be gained by observation of the animalculæ. The eminent German naturalist, Ehrenberg, as one result of very extended observations, established the fact, that the existence of visible animalculæ generally indicates the presence of a lower series of invisible animalculæ descending in magnitude, to the smallest monad of the most simple structure, so small that there is probably no smaller organized creature on which it can feed; while, as is commonly conceived, by arresting organized matter on the very limit of the

organic world, and converting it into its own nutriment, it furnishes, in its turn, sustenance to higher orders of animalcular life. Be this as it may, it is very certain that the presence of animalculæ in large numbers indicates the existence of animal and vegetable matter usually in a state of decomposition, which invariably acts injuriously, if the water containing them is used largely for purposes of food, and the effects may be more immediate and marked when the animalculæ are large and numerous. In respect to vegetable matter, it is to be observed that when water is kept stagnant, and exposed to the sun in moderate temperatures, vegetable infusoria of the class called algæ, and also fungoid vegetation, appear rapidly. Many tribes of these vegetable productions appear to die with great rapidity, sometimes in one or two days, and then decompose. Immediately after these, animalcular life appears. Stagnant water is the most favourable to this order of vegetable productions, which in giving rise to animalcular life, appears to keep pace with the animalized excreta discharged in the house drainage of towns. This insalubrious order of production is indicated by the smell in stagnant or nearly stagnant ornamental waters, such as the stagnant portions of the Serpentine River, which have often excited so much declamation. Certain degrees of motion in water are unfavourable to the production of algæ and other infusorial plants, the tissues of which are destroyed by brisk motion; but a large proportion of them are found in slow running waters or open canals with little traffic, such as the Regent's Canal. In summer time the extent of pollution here is perceptible to the smell over the bridges, and at some considerable distance. The same round of life and death also takes place in open and shallow reservoirs, and in open cisterns where the water is frequently changed.

Light, however, appears to be necessary to the production of infusoria and fungoid vegetation, and their formation is prevented by such covering as excludes the light and heat of the sun.

Whilst exposure and stagnancy, or slow motion, thus increase the animal and vegetable impurities in water,

they likewise increase its mineral impurities, by the increased evaporation, which leaves a larger proportion of mineral matter as a residuum. Thus we have had examples of shallow spring water, or agricultural tile-drainage water, of only four degrees of hardness, taken from the tile-drains, as in Richmond Park, increased to eight degrees of hardness in water from the same soil, after it has stood for a time in ponds ; water of only two or three degrees, at its source, is found to increase to ten or twelve degrees of hardness in canals, a difference not to be accounted for from the qualities of any puddlings of clay, or strata containing lime, over which the water might have passed. Mr. Cooper gives an instance in the Surrey Canal, a canal of little traffic, which is fed from the River Thames at Rotherhithe. He examined it, by taking specimens of the water at several points between its entrance at Rotherhithe and its termination at Camberwell. The examination showed an increase of specific gravity, an increase of organic matters, and a corresponding increase of saline matters, and of hardness, from its entrance to its termination. This progressive increase of impurity up to the termination, he could not but ascribe to the process of evaporation, combined with the smaller amount of traffic which there was towards the end of the line.

Dr. Angus Smith thus states the result of his examination of the condition of the River Thames, in respect to the quantity of organic matter which it contains.

As the quantity of chlorine chiefly as common salt is a constant accompaniment of organic impurity, there being between common salt and animal life a necessary intimacy, I will give here the rate of increase from Pangbourne down to London Bridge :—

		Grains of chlorine.		Grains of common salt.
	Pangbourne . . .	·172	=	·287
	Windsor . . .	·209	=	·349
Half ebb	Richmond . . .	·184	=	·307
	Hammersmith . .	·184	=	·307
	Chelsea . . .	·283	=	·472
	Lambeth . . .	·481	=	·801
	London Bridge . .	·494	=	·824
High water	Lambeth . . .	·753	=	1·256

This increase agrees with the increase of organic matter and of organic life got by microscopic observation. High water is

believed by some to be the worst state of the Thames. At the same time it covers over a large extent of surface with a more wholesome covering than it before had, and receives into itself instantly sewers which would otherwise become less rapidly diluted, and deprived of the power of doing evil. Low water, I believe, is not considered wholesome either in London or elsewhere, nor can we expect it to be so; it must, however, be unwholesome to a less extent in London than formerly, because the day ebb leaves, instead of mud, a pretty clean gravel, where there is no inlet or impediment to the flow of water. This is not the case with the night ebb, which leaves a large quantity of mud, there being no steamers to stir it up and keep it in suspension whilst the water moves onwards.

He thus describes the condition of the water in respect to animalculæ :—

Richmond water began to show very strongly the change caused by towns; it contains in a gallon—

Chlorine . . .	·184 grains.
Equal to, as common salt	·307

A quantity of brown flocculent matter fell to the bottom of the vessel, containing animalcules in great abundance, with some of a kind entirely different from any yet perceived higher up, such as the eel-like animals *vibrio fluviatilis*. This creature is about $\frac{1}{80}$th of an inch long, I believe, but I could not well measure any of them, they were in such constant motion. The change in the nature of the deposit is sufficiently indicated by its appearance, the animalcules preceding seldom going beyond $\frac{1}{400}$th of an inch, many of them much smaller. There was also a patch of dirty brown on the side of the vessel, which, when examined by the microscope, was resolved into thousands of animalcules, the *navicula fulva*, I believe. This appearance I shall speak of more fully afterwards, as a test not easily mistaken. It contains phosphates and silica.

At Hammersmith I can only say the same of the water, the quantity of chlorine in a gallon was the same = ·307 of common salt. The animalcules the same kind, and the flocculent precipitate with the brown deposit of the same character, containing phosphates, silica, and organic matter.

The river water opposite the water-works at Chelsea contained—

Of inorganic matter .	23·10 grains in a gallon.
Of organic and volatile	4·2
	27·2

At another time—

Inorganic matter .	19·16
Organic	2·58
	21·74

Of chloride of silver got 1·15 = ·238 grains of chlorine, or as common salt, ·472.

The number of animalcules was greater here than at Hammersmith, of the smaller kind, chiefly from $\frac{1}{700}$th to $\frac{1}{400}$th of an inch; with the exception of the naviculæ forming the brown deposit before mentioned. There was also a mass of flocculent brown matter, but it was not very thickly inhabited, it probably had passed the stage of most active animalcular life when I examined it, as the amount of matter left material enough for the formation of many little creatures. This is borne out by the water at Lambeth.

The water opposite Lambeth Palace did not get clear after long standing, containing a fine clay not dissolved by acids.

When burnt there is a strong acid smell, and there is also nitric acid perceptible in the remaining salt. It has therefore the qualities of well water in a badly drained district, or water too near any source of organic impurity. Such waters do not leave carbon when boiled down and heated, the saltpetre burns the charcoal.

Water got at Hungerford Market had

Inorganic matter . .	47·55 grains in a gallon.
Volatile and organic .	13·7
Of matter in suspension	61·25

The organic matter burnt had the smell of rotten wood.

A specimen got between Blackfriars Bridge and Southwark Bridge, near the London side :—

Inorganic matter in suspension .	43·12 grains.
Volatile and organic	13·12
	56·24

This specimen gave a smell like burning wood also when boiled down and heated.

Both the specimens last mentioned contained animalcules larger, fatter, and uglier than any preceding. One creature was observed about a thirtieth of an inch in size. When the deposit of mud was removed and the water seemed clean, these specimens, along with the specimens from Richmond and Hammersmith, were allowed to stand some time. In a short time the flocculent matter spoken of was formed, brown like iron-rust, and the covering of one side of the vessel by the brown naviculæ took place also on the side next to the light. Phosphate of magnesia and ammonia was got by dissolving and adding ammonia.

Dr. Hassall, who, as a naturalist, gave a microscopic examination of the waters of the Thames, and also of the other waters supplied, confirms and extends the indications afforded by the examinations of Dr. Angus

Smith, as to the general impurities of the supplies, as delivered to the population. The tenor of these scientific investigations is to confirm the popular impressions derived from sight and taste as to the nature and quality of the supplies delivered. In respect to microscopic examinations of water, it appears to be due to state, that it is misleading to suppose that every drop of water contains such amounts of animalcular life as are frequently displayed in the representations of the results of microscopic examinations of river waters. Such quantities are only obtainable from the RESIDUES of the ordinary water supplies, except in very gross cases, where the water appears to the eye to be muddy and discoloured! At some periods of floods, the colour of the water, and also the appearance of large visible animalculæ, render it, as delivered in some of the districts, not only repulsive as a beverage, but unfit for use even for baths.

Not to speak of the important effects of chemical filtration, such as that which is displayed in the evidence of Professor Way, and adverted to by Dr. Angus Smith and Mr. Cooper, it is proper to observe that filtration, which consists merely of a process of straining, detains visible animalculæ. The filters commonly sold do indeed, according to Dr. Hassall, detain the invisible animalculæ. The existence of visible animalculæ in water which is professed to be filtered, is decisive, as to the unskilful and careless manner in which the process has been conducted; whilst the delivery of coloured water, abounding with animal life, displays an absence of all proper consideration in those who supply it, and a contempt of private convenience as well as of what is required for the public health.

There can be no doubt that animal and vegetable impurities such as are found in the New River, in the River Lea, and in all rivers derived principally from surface washing or the surface drainage of land, (independently of the pollutions from the sewerage of towns,) are largely augmented by the mode in which the supplies are conducted in coarsely constructed open earthen conduits, and exposed in open reservoirs and cisterns;

but we have deemed it a superfluous labour to attempt to determine how much of the augmented impurities is due to ill-conditioned, open cisterns; how much to ill-placed open reservoirs, or to open channels of conveyance; neither have we thought it necessary to attempt to determine what may be their precise effects on the public health. It suffices that these visible pollutions and the disregard of coolness, by their effect on the perceptions of sight and taste, indispose the poorer population to the use of water as a beverage; that is to say, that they dispose, incite, and in many instances it may be said, drive them to habitual indulgence in ardent spirits and fermented liquors. The following answer to a question put to Professor Clark, displays the more cursory information given upon this point.

Can you state what effect on health is likely to ensue from the constant use of water containing animal or vegetable impurities?—I am not prepared to make any statement upon that subject; nor am I aware that, in regard to a question of so much interest, there has been much accurate information obtained. However, there is one very obvious consideration as regards the health of the inhabitants, that if you have water not fit for drinking, in which there is matter offensive in any degree, by so much as the water is offensive you lessen the habit of drinking water. Now, you cannot restrict the supply of water to such quality as is naturally repulsive; you cannot thus render the inhabitants abstinent from water, without interfering with the healthful functions of their bodies. It was with no small concern that I learned how few of the inhabitants of London, and especially of the lower orders, drink water. In making my experiments upon these waters, when I inquired of the servants about me how they liked particular waters, it was with perfect surprise I discovered that they—generally mere lads—knew nothing about the taste of the water. They are the same sort of persons as would be accustomed to drink water in other places, but they have other beverages here. I should, perhaps, not speak as to the general habit of the inhabitants, but only of what little I have observed in such circumstances.

Dr. H. Gavin, in speaking of the delivery of water often loaded with sedimentary matter to the population of Bethnal-green and the eastern districts, observes, that as a consequence the water becomes unpalateable to the poor who have no means of filtration.

They therefore have recourse to beer, which has become a

common beverage of the people of London, as much, if not more, from the impurity of the drinking water supplied to them than from any other cause. I have, in making inquiries among the poor, constantly had this reply,—"We cannot drink the water Sir, it is so nasty; it makes me ill." This common observation among the poor is borne out by the evidence of strangers, who generally complain of slight diarrhœa after drinking the London water for a few days. I have every reason to believe, that were a pure and wholesome water supplied to the poor of London, it would be found that in a short time intemperance and beer-drinking would become much less common. This evidence is the result of my inquiries among the poor themselves, continued for several years.

Mr. Challice, the surgeon, and chairman of the Board of Guardians at Bermondsey, concurs with others familiar with the habits of the poorer classes, that a purer supply of water would have the important effect of inducing amongst them a habit of drinking it, and says—

The stomach is nauseated by bad water, and, being compelled to take a certain quantity of fluid daily, if the water does not agree with people they must take some other drink, such as beer, &c.

Does not that form the excuse with many of the labouring classes?—They could not do without other stimulants, if the water supplied in the neighbourhood is bad as well as the state of their dwellings.

Would you under such circumstances actually advise them to take alcoholic stimuli?—Undoubtedly I would.

This view of the evil effects of the want of proper water supplies on the population is fully corroborated by the most experienced City missionaries and district visitors.

Much of the evidence indeed proceeds upon the assumption that the persons who drink water are a small and exceptional class, whose wants or whose likings are only entitled to incidental attention. Thus the witness on behalf of the Lambeth Water Company, Mr. Richard Phillips, the chemist, when questioned as to whether the water then delivered might not be objectionable on account of the quantity of offensive animal matter which it contained, says, "it would not be so pleasant;" as if the subject were, from

the incidental or occasional use of the water, one of no great moment, affecting only some few people. Thus a former surveyor of the City Commission of Sewers, when examined before a Committee of the House of Commons, in describing the state of drainage of Leadenhall-street and Cheapside, said that in consequence of the inclination for the discharge of surface-water that thoroughfare had no sewer in it; whereon the following question was put and answer given:—

As far as surface-drainage is concerned?—Yes, the inhabitants of Cheapside, generally speaking, have got cesspools; they perforated the yellow clay or loam, and got into the gravel, and whatever is thrown into the cesspool mixes with the water and earth;—that is for the benefit of the water-drinkers.

Whilst, however, he thus expresses his own view of the little importance of the water drinkers, he unwittingly testifies to the appreciation of clear water by the poor people, who were ready to take it even from the cutting of a sewer; for the surveyor continues:—

The water that was pumped out to make the sewer along Watling-street was perfectly pure, and persons from the neighbourhood came to catch it as it fell from the pump, it was considered to be so good and so much superior to everything they had ever had before.

According to the view of this officer of the Corporation charged with such important measures affecting the public health, it must be presumed that the water-drinkers are regarded as a small or eccentric sect in the City, and that such pollutions of their beverage are things of no moment, calling for no remedy, and treated as a joke rather than otherwise. But it is because water drinking has been, and is yet so regarded, and treated, that the great majority of the labouring population are drinkers of fermented liquors and ardent spirits, and are led into those excesses in the use of them which are fatal to health, industry, and content.

An entirely opposite course of feeling and action appears to us to be dictated by the proper consideration of the public health, by justice, and by every sound principle of public administration. We consider it of primary importance that every practicable exertion

should be made to remove discouragements, and furnish incitements to temperance, by the superior quality and condition of the water supplied for domestic use, and by the convenience of its distribution. We shall show ground for our belief that this may be done, with a reduction of existing charges, and that it is practicable to present to all, supplies of water of such quality and purity as every one might desire to see and use at his own table.

When making provision for a supply of water to a town population, we deem ourselves bound to consider the peculiar privations of the poorer classes. In the case of the population of a vast metropolis it appears to us to be especially necessary to estimate their wants and inconveniences. With no population is the quality of water for drinking, for cooking, or other domestic uses, not a matter of primary sanitary importance; but with a densely-crowded town population, the need of care as to the quality of the supplies for every use is peculiarly urgent. From a town population being lower in general health than a rural population, from having amongst them a larger proportion of weakly, sickly, and susceptible persons, the health of a town is more powerfully affected than that of a rural district by inferior qualities of the common beverage. Towns are at present never free from epidemics, and in epidemics, when the general health of the population is more than ordinarily depressed, the effects of impurities in water are strongly marked. This, as we have shown, was strikingly exemplified during the last epidemic, when effects of variations in the quality of water became visible that were observable or observed at no other time. A rural population, besides being less susceptible, have in most districts opportunities of obtaining comparatively pure water, or of avoiding supplies of extreme impurity; they have, moreover, for children, cheaper and purer supplies of milk; but a town population has less choice of natural supplies even if they could bestow equal labour in obtaining them. In the rural district rain water is commonly available in aid of other supplies. In the

urban districts the rain, falling through the excessive smoke of an impure atmosphere upon the soot and dust and other filth collected on the roofs of town buildings, the water from this source is generally abandoned, as unsuitable for the population; nor from the excessive and increasing pollutions of shallow wells, by cesspools, drains, sewers, and graveyards, is this other common resource of a rural population, available for an urban population, which is now, and must be hereafter, dependent on artificial or pipe-water supplies, obtainable only by engineering works on a large scale.

In the evidence on behalf of the suitableness of the existing pipe-water supplies, and in the new schemes for additional supplies, it is usual to present, as sufficient proof of quality, bare chemical analyses, the defects of which we have already stated; and in relation to those products which chemical analysis does ascertain, it is commonly assumed that the variation of a few grains in the gallon of animal, or vegetable, or mineral matter, can be of no moment. We are now enabled, from the knowledge of a difference in the perceptible state of the air of one place as compared with another, to predicate with certainty, differences in the average sickness and mortality amongst a large class of the population, though no definite result might be perceptible in or predicable of any individual of which that same class is composed. As it is with differences in the air, so we apprehend it will be found with differences in the condition of the water, that all these ingredients must produce their effects in the mass. Thus three or four grains of organic matter are treated as of no real importance in a gallon of water, but in the day's supply to the population of the metropolis, the aggregate is several tons, liable also to augmentation, and, in the various known modes of use or abuse, certain to be placed in conditions favourable for putrefaction and the injurious diffusion of its products. The very minuteness of the quantity serves, under ordinary circumstances, to render the water more pernicious to the public health; the noxious effects are slow, not appreciable at the time, but not the less real. If the quantity

of the impurity were larger, it would nauseate the stomach and lead to the discontinuance of the use of the water, or to its correction. Although in the warfare against rival schemes by the existing trading Companies, every additional grain of lime in the gallon of such water as that of the Colne, for example, is treated (we believe justly) as a serious additional impurity, yet the sixteen grains per gallon contained in the Thames, Lea, and New River waters, are held forth as of no real consequence. The importance of this mineral ingredient, however, is only to be correctly estimated when viewed in the aggregate, when the sixteen grains per gallon becomes, in the day's supply of forty-six millions, twenty-six tons of lime, which we find affecting every domestic operation, and see accumulated as a coating in kettles, in the pipes of baths, in the boilers of steam-engines, and so on; destroying 25½ oz. of soap in every 100 gallons of water for each degree of hardness, or single grain of lime contained in a gallon of water; causing steam-boilers to be burned out, not unfrequently to burst; and, also, inducing increased expenditure in fuel to raise steam for power, or to boil water for any purpose,—as it has been found that each degree of hardness in water requires additional heat to raise it to the boiling point. For supplies on the small scale, there is less use in following out all the particular defects observed by common experience, or ascertained by chemical analyses, inasmuch as the means of removing or preventing them are seldom available, unless at a disproportionate cost of labour and expense. But it is a circumstance of important promise for crowded populations in larger town districts, which we may enunciate as an economical axiom, that the economy and facility of supplying a commodity which furnishes the means of improvement, increase in proportion to the quantity of the commodity consumed.

Having adverted to the adventitious qualities of the water supplies of the metropolis, the gaseous pollutions, the pollutions of animal and vegetable matter, and the defects occasioned chiefly by mismanagement of the temperature at which water is delivered, we now sub-

mit the chief results of our investigations in relation to the mineral or earthy matters contained in these supplies.

In the course of those local investigations which we have had to direct for the application of the Public Health Act to about 60 towns in different parts of the country, there have been examinations of upwards of 150 rivers and running streams, besides other water sources, of which we have had between 400 and 500 specimens analysed, to determine the most eligible for town supplies. These analyses have been chiefly conducted by Dr. Lyon Playfair. He attests the general conclusion; that, as compared with all these waters, Thames water is above the average, or in excess in regard of organic animal and vegetable matter, (apart from the influence of the sewerage of the metropolis,) and is also in excess of earthy matter, that is to say, of carbonate of lime. It is nearly as two to one in hardness of the average of all the water supplies which we have had examined and selected for towns; that is to say, whilst the average of the waters found available for new districts was about 8 degrees of hardness, the average of a set of analyses procured from Professor Brande of Thames water supplied by the Companies, was 16 degrees. Dr. Lyon Playfair has not found the hardness of his average specimens of Thames water quite so high. But there was reason to believe, as is shown in the report of Dr. Angus Smith, that the reduced hardness which was found in the specimens taken from near the metropolis was occasioned by the excess of animal refuse and other pollutions. The waters of the river Lea and those supplied by the New River Company are essentially of the same character as Thames water in respect to hardness.

Degrees of hardness (a term invented by Professor Clark) are taken to mean, the number of grains of carbonate of lime contained in a gallon of water. Those who have used rain water for washing, or who have been accustomed to the use of a very soft water, would begin to feel water as not soft, at about five degrees of

hardness. For an elaborate exposition of some of the characteristics of waters having this quality, we would refer to Professor Clark's evidence.

It is not, however, easy to obtain direct evidence of the sanitary effect of this quality, or of any other particular quality of water, of which very little is drunk by the population. Hippocrates, the only physician among the ancients who appears to have observed widely the effects of waters upon the health of populations, who were probably more restricted to the use of water as a beverage than town populations in modern times, adverts generally to the effects of hard water as pernicious; we are left to presume that the quality which he denoted as hardness was essentially the same as that now popularly understood. He, as well as Celsus, and other ancient physicians, however, who treated on dietetics, assigns the first rank in salubrity to rain water, that is to say, to soft water. Celsus thus classes waters:—*Aqua levissima pluvialis est; deinde fontana; tum ex flumine; tum ex puteo; post hæc ex nive aut glacie; gravior his ex lacu, gravissima ex palude.*

Hippocrates says that "the healthy and strong may drink such water as comes in their way indiscriminately, but they who drink water for the recovery of health must be careful in the choice they make. The lightest, purest, and softest waters are most fit for those who are apt to be costive, whereas the hardest do most service to those whose bowels are too moist and phlegmatic."

Adopting this aphorism, we must observe the effects on the stomachs of the susceptible as the best tests of the qualities of waters. Lime, in all its forms, it is well known, diminishes the solvent power of water; it is probable, therefore, that it impedes the process of digestion and assimilation. The observation of Dr. Sutherland, as a physician, enables him to give the following evidence on this point, which agrees with the observations of other physicians. The water to which he refers as in use at Liverpool, is water of about the same degree of hardness as the Thames

water, but it is derived from deep springs in the red sandstone, and is free from the amount of vegetable and animal matter contained in the Thames water.

Having lived for a number of years in Liverpool, a town which has a supply of very hard water for domestic use, my attention has for a length of time been called to the fact, that the continued use of this water has a somewhat peculiar effect on the digestive functions in certain susceptible constitutions. There are so many local causes of disease in the town, which may be left behind by going to other more favourable localities, that it is not very easy to state positively how much injury may be done by the quality of the water alone, but after some experience and observation, both in myself and others, I arrived at conclusions which I frequently expressed several years ago, and which nothing has since occurred to alter, and these are, that in the class of constitutions referred to, the hard water tends to produce visceral obstructions; that it diminishes the natural secretions, produces a constipated or irregular state of the bowels, and consequently deranges the health. I have repeatedly known these complaints to vanish on leaving the town, and to reappear immediately on returning to it, and it was such repeated occurrences, which fixed my attention on the hard selenitic water of the new red sandstone as the probable cause, as I believe it to be, of these affections.

Nearly all the leading medical authorities who have in modern times had their attention drawn to the subject, agree in giving a decided preference to pure soft water for domestic use. Haller says—

Mountain water, as it is pure and cold to the taste, is also beneficial to the health for drinking. If it cannot be obtained river water may be resorted to. Well water I put in the last place, although everywhere it is agreeable for its coldness. It is almost always hard, unsuitable for dissolving soap and for cooking vegetables. The water of lakes, even although they may contain the purest waters, and appear pellucid, nevertheless become tepid from their isolation, and are flat and vapid.

I know, therefore, no water more fit for the use of man than that from rain, which, distilling by percolation, flows crystalline, and of the lightest quality through quartzose sandy soil or pure rock, even although it be somewhat heavier than rain water; cold but not easily frozen in winter, and even pertinaciously flowing in the midst of a rigid frost: not changeable by rain; making a lather easily with soap; boiling vegetables to softness; not easily becoming putrid; neither collecting greenness nor retaining it; easily allaying thirst.

Dr. Todd Thomson, an eminent physician lately

deceased, states in his work on the domestic management of the sick room—

The best and the most universal drink for the sick is *water;* but the qualities of water differ, according to the source whence it is procured. The fewer foreign ingredients it holds in solution, the greater are its diluent properties, thence, either distilled water, or rain or river water filtered, are the only kinds proper for the use of the sick room. Hard water under whatever name it is found, whether as spring water or pump water, or well water should be excluded. The impurities of river and rain water are merely held in suspension; consequently they are readily removed by filtration. Water itself is an aliment; many individuals under certain circumstances have lived for a considerable time upon it alone. Those who live chiefly on animal food require more drink than those who eat much vegetable matter. Water composes the greater part of all the fluids of the body; namely, the blood and the secretions, and when it is withheld these become too acrid, and act almost as poisonous agents upon the nervous system.

The celebrated *Dr. Heberden*, in a paper read before the College of Physicians, on June 22, 1767, and published in the first volume of the Transactions of the College, after enumerating the various calcareous impregnations of the pump waters of London, says:—

It might be expected, that all these disagreeable substances should remarkably taint this water; and yet the London pump water is by many esteemed for its goodness and purity. But, however, it may be esteemed, it unquestionably differs from pure water in its taste, and colour, and touch, as well as in many observable effects. Flesh boiled in it turns red on account of the predominance of the nitrous acid; and it occasions in a strong degree all the other well known changes in certain bodies peculiar to hard waters. Tea and coffee made with it, are by most palates readily distinguished from these liquors when made with soft water; and the difference will be as easily perceived by the touch, if the hands be washed in pump and soft water.

It must, I believe, wholly be resolved into the power of custom, that the inhabitants of London are so satisfied with this peculiar taste of their water, which is, as I have often been a witness, much complained of by those who came hither from foreign countries, as very disagreeable to their palates, and sometimes as offensive to their stomachs. Custom makes the Greenlanders fond of the taste of train-oil, and its power is no doubt as great in reconciling the drinkers of bad water to its ill taste. But though custom can reconcile our palates to the taste of limestone, spirits of vitriol, spirits of salt, and aquafortis, it may still be questioned whether

it can as easily make health consistent with the effects of these rough and by no means inactive substances. They have been by many physicians suspected when found in water of occasioning pains in the stomach and bowels, glandular tumors, costiveness, where the simple limestone prevails, and diarrhœa where much of it is united with acids; and the uninterrupted drinking of such waters for a long time may probably be the cause of many other disorders, especially to the infirm and to children. Hence a change of place may often be of as much use to weak persons from the change of water as of air.

He recommends the partial use of river water, but says that—

The Thames water has a share of all these impure ingredients; but as it is a much larger body of water, it is proportionally less infected by them. There is an inconvenience attending the use of Thames and New River water, that they often are very muddy, or taste strongly of the weeds and leaves. The latter fault is not easily remedied.

Rain or snow water is much preferable to river, or to any other natural water. The purest of all waters might be obtained by distillation.

It being, therefore, a matter of some importance to drink pure water; if any one be desirous of procuring it by that most efficacious and universally practicable method of distillation, it may be useful for him to attend to the following observations, &c.:—

It is generally believed that the swelled throat, which is endemial in a slight degree in several parts of England, as well as so remarkable near the Alps, is owing (though not to snow water) yet to some bad quality of the waters of those respective places. I have reason to suspect that the common swellings of the lymphatic glands sometimes owe their diseased state to the water which the patient drinks. In these cases, as well as in many chronic pains of the stomach and bowels, a course of distilled water might be as beneficial as the most celebrated mineral waters are in any other disorders, and might prove no inconsiderable addition to the Materia Medica.

He cites, as proof of its wholesomeness, the case of Francis Secardi Hango,

who made distilled water his constant drink, without the addition of wine or any strong liquor, to the last, and lived with remarkable good health to the age of 115 years.

We certainly find, on inquiry, instances of more bad consequences from drinking London well water, the chief water used for drinking in the metropolis, than the medical profession are aware of. Invalids

who have used distilled water, acquire a strong distaste for the common well, or hard water, notwithstanding its coldness and its occasional briskness, from carbonic acid gas. They complain of it as tasting "inky." It is stated to us that at Malvern, where the spring water in the highest reputation for medicinal quality is a water only remarkable for its purity, there being some variations in the quality of the springs, the softest water is found to agree the best with invalids. Apparatus for the distillation of water having been proposed to be introduced on board the French navy to obviate the possible failure of water stores, the Minister of Marine appointed several medical commissions to give distilled water to the men and observe the effects upon them. The trials were made separately, and the results were reported to be uniformly favourable.

On consulting the wider and more popular experience where changes have been made from the general use of hard water to that of a soft water supply, as at Paisley, and several other towns in Scotland, and at Bolton, and several places in Lancashire, the tenor of the answers is in accordance with the preceding information. Thus Dr. Paton, of Paisley, states to us, in respect to the supply of soft water to that town:—

It is of a very pure quality containing little, if any mineral impregnation, being mostly rain-water collected over hills of whinston or clay porphyry. The pipes being always kept full there is very little decomposition within them and a constant supply. Most of the inhabitants, I understand nearly 90 per cent of the population, are in the habit of using it, many dyers and printers, who have the river running close to them, avail themselves of it, even at a considerable expense. My own observations on the water of other places as compared with this, lead me to the conclusion that no expense ought to be spared to supply towns with pure water, and that without any mineral impregnation. This, however, can only be accomplished by collecting the water from high grounds formed of trap or primitive rocks, and not from soils impregnated with lime, &c. For such a place as London, though the water was brought from Wales, the ultimate advantages would more than counterbalance all the trouble and expense, but some place perhaps could be found nearer and of sufficient height to give a constant supply. I was lately on a

visit to my native place, Largs, in Ayrshire, and, when there, took a drink of water from a well that has always been esteemed very pure, but comparing it to the water of Paisley, I thought from taste that it was the opposite, being strongly impregnated with carbonate of lime. Upon testing it the quantity was not great, the feeling had only arisen from the extra sensibility of my taste, being accustomed to water without any impregnation, so that pure water is always pleasanter than hard water, even though there was no danger in the use of the latter.

Dr. Leech of Glasgow, with reference to the Gorbals' Gravitation Water-works of that city, states:—

My attention has been called to the bearing of the question of pure soft water supply on the public health. The Gorbals water is very soft and pure. The new supply has been introduced about two years, but in consequence of the bad water supply which existed before the new water was introduced, my attention as well as that of my medical brethren, was directed to the question for a long time previously. The comparative value of the new soft supply over the old hard supply, has been matter of discussion at the Glasgow Southern Medical Society, of which I was president two years. It was the unanimous opinion of the medical profession, that great benefits of a sanitary kind had followed in the substitution of the soft water, on the principle of constant supply. It has been observed that since this change, urinary diseases have become less frequent, especially those attended by the deposition of gravel. So far as experience has gone, my own opinion is, that dyspeptic complaints have become diminished in number. With the same reservation as to time, it is the opinion of the medical profession, that fever has numerically diminished, and that the cases that occur are more amenable to treatment by the use of the soft water supply, than they were with the former supply.

During the late cholera there was a remarkable circumstance which deserves notice, as compared with the epidemic of 1832. Since the former period the population of Glasgow, south of the Clyde, has nearly doubled, and with this exception and the introduction of the soft water supply, the circumstances might be considered as the same at both periods. In one district, the parish of Gorbals, the attack in 1832 was fearful, while Glasgow, north of the Clyde, also suffered severely. During the late epidemic, Gorbals parish furnished comparatively a small number of cases, while the epidemic in other parts of Glasgow was very severe. The unanimous opinion of the Medical Society was, that this comparative immunity was to be attributed to the soft water supply.

Dr. Cunningham, of Glasgow, gives testimony to the same effect.

We have obtained similar information from public officers, and competent and disinterested persons, some who have been accustomed to drink the soft water coming from the mountain granite in Scotland; others who have been accustomed to drink the soft water which descends from the slate rocks in Wales, and who have afterwards lived in the metropolis. They have described the hard well-water of every variety brought to the table, as comparatively disagreeable to them. Accustomed to the purer soft waters, they perceived peculiarities in the hard well water of which the persons habitually using it did not appear to be sensible.* On the other hand, persons who have been accustomed to the use of hard waters for drinking, have not experienced any repugnance to the change to soft water, and when it was delivered in a state of equal coolness, clearness, and æration, have given to it the preference as a beverage. Some well waters are agreeable for the briskness derived from free carbonic acid gas, in addition to coolness. The stimulus of carbonic acid gas in water is, however, akin to the stimulus of carbonic acid gas in malt liquor and wine, and is for other reasons a quality of doubtful salubrity for a general beverage, and might be left to be added artificially by those who like it.

On animals confined to the use of water for drinking, and using it in very large quantities, the effects of varia-

---

* Modern populations who use water as a beverage are found to be as nice and discriminating in its qualities as were the ancients.

Sir George Staunton ("Embassy to China," vol. ii., p. 69, 4to) says, "Persons of rank in China are so careful about the quality of the water intended for their own consumption, that they seldom drink any without its being distilled."

"The old men of Brazil, according to Piso ('De Medecin, Brasil,' 1648), are as nice in their choice of waters as people are with us in distinguishing the qualities of wine, and they accuse persons of imprudence who use them all without selection. They use the lightest and sweetest, and those which, falling from elevated grounds, leave no sediment"

(Bruce's Travels in Abyssinia.) In Egypt they prefer the water of the Nile. The gravel is said to be "universally the disease with those who use water from the draw-wells, as in the desert."

tions in quality are likely to be more distinctly developed than in men, and thence are referred to in another place as indicative of the relative salubrity of hard and soft water. Dr. Playfair refers to this:—

Horses have an instinctive love for soft water, and refuse hard water if they can possibly get the former. Hard water produces a rough and staring coat on horses, and renders them liable to gripes. Pigeons also refuse hard water if they obtain access to soft. Cleghorn states, that hard water in Minorca causes diseases in the system of certain animals, especially of sheep. So much are race-horses influenced by the quality of the water, that it is not unfrequent to carry a supply of soft water to the locality in which the race is to take place, lest, there being only hard water, the horses should lose condition. Mr. Youatt, in his book called "The Horse," remarking upon the desirableness of soft water for the horse, says, "Instinct or experience has made the horse himself conscious of this, for he will never drink hard water if he has access to soft; he will leave the most transparent water of the well for a river, although the water may be turbid, and even for the muddiest pool." And again, in another place, he says, "Hard water drawn fresh from the well will assuredly make the coat of a horse unaccustomed to it stare, and will not unfrequently gripe or further injure it."

It was long a prevalent belief that lime or other matters contained in water were the cause of stone; but that dreadful malady occurs in different districts, with very opposite qualities of water, and among persons who are not water drinkers. It is chiefly referred in the present day to a disordered state of nutritive functions apparently oftener caused by errors in solid than in liquid diet.

It appears, however, to be undoubted that the number of calculous complaints in the hospitals, as at Paisley, have greatly diminished, and that in the same ratio as consumption of soft water has increased. At Bolton, also, the most experienced practitioners independently attest the fact of the diminution of calculous complaints since soft water was introduced; they express confident opinions that this diminution may be ascribed to the use of soft water, which may be the fact, although the disease which sometimes occurs in infants of a year old, may not be caused by the use of hard water. Dr. Thomson, in his report on the well waters of Glasgow, states, however, that an excess of any

form of lime in the food "is highly objectionable, "as it is very frequently the cause of gravel and stone, "and enters into the composition of many concretions "which gather in the human system. So powerful is "its influence that when a person has been recovering "from this painful disorder, a recurrence of the disease, "in all its violence, has been occasioned by the presence "of even a small quantity of lime in the water used "to drink. It follows, then, that the less the proportion "of lime is in water the better it is fitted for such "cases; but although this disease, in its most aggra-"vated form, is fortunately not common, the depo-"sition of minute concretions of lime is far from being "a rare occurrence. In country situations in the low-"lands, the wells often contain much lime in solution, "and the inhabitants do not appear to be liable to "gravel; but they are placed in totally distinct circum-"stances from the dwellers in a large and populous "city."

Dr. Wolstenholme, of Bolton, gives the following testimony :—

May 3, 1850.

I have been acquainted with the character of diseases in Bolton for 35 years, and I have no doubt that gravel and calculous affections are less prevalent in the last few years than they were in the earlier period I speak of, viz., from the years 1815 to 1825. I attribute the improvement mainly to an ample and unlimited supply of pure soft water by the establishment of the Bolton water-works in the year 1824, and partly to the diminution of drinking malt liquor to excess. If I might be allowed to guess at the proportion of good effected by the different causes, I should say that three-fourths are the result of good water, and the other fourth the result of more temperate habits.

Mr. Robinson, surgeon, Bolton, has expressed similar views.

We submit the evidence as we have received it, believing, however, from facts such as are here indicated, that the *cause* of calculous complaints in different districts is a subject which requires much further investigation.

On the other hand, it has been alleged, that lime is useful in waters, as a constituent of bones: on this

point Professor Clark gives the following in answer to an objection made to his process for reducing the hardness of river water:—

Was there no objection made to the quality of the purified water?—One objection was made, on the suggestion, I understood, of a medical author of some name. It was, that the depriving the water we drink of its chalk, might prove injurious to the bones of the inhabitants. The idea was founded on this consideration, there is lime in chalk and there is lime in bones; if you deprive the water we drink of one thing that contains lime, you must also deprive our bones of another thing that contains lime.

Had you no reply to offer to that objection?—Although much concerned to discover that the state of medical science in London could permit such a suggestion being made, and although much amused at the earnest conviction with which the objection was repeated, I certainly did not think a scientific answer called for; but I did suggest that the purifying process might still leave as much lime as was required for the bones, since, in the town of my residence, there had been long water in general use, containing much less lime than the purified water would contain, and yet the inhabitants were among the largest boned of the Queen's subjects.

It has been alleged, that Thames water is found to keep better than any other for long voyages. We find the fact to be, that sea captains, who themselves use grog or fermented liquors as their beverage, are apt to be culpably negligent in the quality of the water which they receive on board, and commonly take that which is near, with little or no selection. The Thames water, in consequence of the quantity of organic matter in it, soon gets into the state of putrefactive fermentation, and when that is over, and it has been ærated with the sea air, it becomes clear and is found to be potable by those on board who take the water unmixed. The practice is, however, becoming frequent of taking water on board which has been deprived by filtration of as much as possible of the putrefactive matter. By captains who pay attention to the subject, the water called the Shaw's water at Greenock, and that taken in at the Islands of St. Helena and of Ascension, are found to be of superior purity.

On the whole, from much evidence of the same tenor as that we have cited, we cannot doubt, that the presence

of lime and other mineral matter deteriorates the wholesomeness and value of water for the purposes of drinking.

In the evidence of witnesses connected with the present hard-water supplies, we find strong allegations of the danger of the introduction of pure water from its powerful action on lead. There can be no doubt of the more powerful action of soft water upon lead under given circumstances; which circumstances, however, we find from experience on a large scale seldom or never occur under a proper system of distribution. Some fatal accidents have been occasioned by the fall of leaves in leaden gutters and cisterns, the infusion of which appears to have caused powerful decomposition. The use of lead piping and lead cisterns has long been objected to, and the remedy would be the disuse of that metal. Iron piping is altogether better and cheaper than lead, and may now, it appears, at no great additional expense, be protected from oxidation by an earthenware glaze. But for the obstinate prejudice of professional men and builders in favour of the most expensive materials, earthenware would have been manufactured and used for the distribution of water. It was so used by the Romans. Vitruvius recommends it as far preferable to lead; he shows that it was used for the distribution of water up to one hundred feet of pressure. He states:—

If the water must be conveyed more economically, the following means may be adopted. Thick earthenware tubes are to be provided not less than two inches in thickness, and tongued at one end so that they may fit into one another.

He then describes in detail the methods, having previously provided against leakage from hydraulic concussions.

Over the venter long stand-pipes should be placed, by means of which the violence of the air may escape. Earthen pipes have these advantages, first as to the work, next that if damaged any one can repair them. Water conducted through earthen pipes is more wholesome than through lead; indeed, that conveyed in lead must be injurious to the human system. Hence, if what is generated from it is pernicious, there can be no doubt that itself cannot be a wholesome body. This may be verified by observing the

workers in lead, who are of a pallid colour; for, in casting lead, the fumes from it fixing on the different members, and daily burning them, destroy the vigour of the blood; water should therefore on no account be conducted in leaden pipes, if we are desirous that it should be wholesome. That the flavour of that conveyed in an earthen pipe is better, is shown at our daily meals, for all those whose tables are furnished with silver vessels, nevertheless use those made of earth, from the purity of the flavour being preserved in them.

The remains of Roman works display their earthenware distributory apparatus. In France, we are informed that earthenware pipes have been laid down, and have been long in action for the conveyance of water at 160 feet of pressure. We have had for purposes of experiment, earthenware pipes made which have only broken at 1,500 feet of pressure. Earthenware is, however, more frangible than iron, and the hydraulic shocks of the intermittent supplies, which often shiver the strongest cast-iron pipes, will, without precautions, break earthenware. On the constant system of supply these concussions are diminished; but by the expedient pointed out by Vitruvius, which would, in the present day, be thought a novelty, by the simple use of an air vessel, the effects of these shocks are effectually obviated. We have obtained specimens of earthenware pipes in use for water distribution in Switzerland, having screw earthenware stoppers and earthenware screw joints. The practical advantages stated from the use of earthenware pipes for water distribution are derived from the higher non-conducting power of the earthenware, the consequent delivery of the water in a cooler state, the comparative freedom from sudden changes of temperature and severe frost, freedom from oxidation, and last of all cheapness.

But whilst strong declarations have been made by professional witnesses, in several places, as to what must be the effect of the introduction of supplies of pure soft water into towns, in substitution of hard water, no idea appears to have been entertained of referring to the experience of those towns where sup-

plies of soft water have been introduced, to ascertain whether any such consequences had been experienced there. We have therefore directed particular inquiries to be made on the subject.

Mr. James Stirrat, bleacher, Paisley, a very respectable and intelligent witness, and a member of the town council of that borough, who has been led to pay very special attention to the subject of the improvement of the supplies of water in Scotland, was asked—

In London, it is stated, that inasmuch as pure water corrodes lead more than other water, a supply of soft water might be dangerous, and might poison the population. How have you found the fact to be at Paisley?—There is no such effect; such an idea is downright nonsense; corrosion in pipes takes place only under the intermittent supply, by the action of the atmosphere on the pipe in a damp state; and, as I have said before, an iron pipe constantly charged will not corrode at all, whether the water be hard or soft, and will last at least four times as long as a pipe where the air is admitted into it.

Other witnesses corroborate the fact that, with some waters, the wear of pipes by the intermittent supplies is frequently very rapid, the rationale being, that oxidation takes place whilst the pipe is empty, and that the oxide is swept away by the return of the water.

In cases where *colica pictonum* and dangerous accidents to health have occurred from the contamination of lead, we believe that it may be ascribed to the intermittent action of water upon long lines of leaden pipe.

It may be useful here to mention, that what, from several experiments, appears to be a simple mechanical preventive, has been discovered by Professor Clark:—

Some of the Bagshot water alluded to had poisoned some of the Queen's hounds, and brought on *colica pictonum* in one of the huntsmen. Through the kindness of Sir James Clark, I obtained a specimen of this water, and in a few days came to the unexpected result, that filtration would separate the lead. Thus a very simple practical means for separating lead, wherever it contaminates water, was discovered. At a marine villa of Lord Aberdeen's, some of the servants suffered in health from lead in water derived from pipes. Sand filters were put up under my

direction at this villa, and subsequently at Haddo House. On making inquiry, recently, his Lordship's agent, in Aberdeen, I learn that the filters have been in use ever since, and that the waters have been tested from time to time, without any lead having been discovered in them. I have been told, indeed, that so satisfied has Lord Aberdeen been with the result, that on hearing of the Count de Neuilly's family at Claremont being troubled with lead in the water, he wrote, recommending the same process being tried there; and, from general rumour, I had previously heard that the process had been adopted there.

I hold it in all cases to be dangerous to allow water to pass through any considerable length of lead pipes, or to allow water to remain for a long time even in short pipes. In the case of the marine villa before alluded to, the water came a considerable distance through lead pipes; I suppose above a quarter of a mile. The water in Aberdeen is brought from the iron mains in the streets, into the houses, by means of lead pipes; and in general without any disadvantage, because the supply from the pipes is constant, and the use of the stop-cock very frequent in a family; but in my class-rooms and laboratory I find that whenever a pipe has been out of use for a few days, the water taken from it affords a trace of lead, which disappears when the water has been allowed to run briskly from the stopcock for a few minutes.

Though we have been informed of no serious accidents from contamination with lead, in any of the towns where new supplies of soft water have been introduced, we believe that minor injuries from such partial contaminations as Professor Clark describes, may occur and pass unnoticed; and that, for this reason, the use of lead pipes should be discontinued as early as practicable. As a question of danger, however, a preponderance of testimony establishes the conclusion, that hard water, with an intermittent supply, is actually more dangerous than soft water with a constant supply.

On the subject of the pollution arising from lead, we have obtained from Mr. Spencer, a chemist at Liverpool, the results of some important experiments which are given in a paper contained in the Appendix.

Lime in any form has a disagreeable effect on the skin: on many delicate and sensitive skins it has a similar irritating effect to that of a long-continued east wind on the skins of the general population. Hard water aggravates the inconvenience and

disagreeableness of shaving, and, with many men, renders it positively painful. These are, in themselves, objections of considerable amount in the aggregate; but for the extension of the use of baths amongst the labouring population of the metropolis and other towns where the new practice has been introduced, as well as for the promotion of habitual ablution, softness of water is a quality of primary importance. The extension of the practice of bathing depends upon its agreeableness, and its agreeableness on the softness and clearness of the water used for baths. Hardness in water not only lessens the pleasantness of washing, but hardens and roughens many skins. It has been remarked both in England and America, that in such districts as have a natural supply of soft water, there is exhibited in the inhabitants a freshness of complexion not to be found in any hard water district. There are persons who have skins so delicate as to prevent the use of soap in any form, and here the application of hard water is even painful. The more robust and healthy do not feel these inconveniences, but in a degree they affect all.

It may be here adverted to, not directly in relation to the qualities of water, but to the effects of increased supply, that after an improved distribution of water into houses, among other sanitary improvements in Hamburgh, there was perceived a very large diminution of the cases of itch, which the medical men of that city attributed to the more abundant supply of water.

Indirectly, and by its operation on the processes of cookery, the hardness of waters may, probably, have some effect detrimental to health as well as to economy.

In this respect, to which we find no attention paid in any of the schemes for water supply which have obtained the aid of Parochial Boards, it has an influence upon the whole of the food of the population, and possesses an importance with reference to the metropolis of which the natives of London are very little aware.

The tenor of the testimony which we have obtained upon the subject is, perhaps, best displayed in the evidence of Monsieur Soyer, the eminent cook.

You are known to the Commissioners from your writings on cookery; and you have doubtless had occasion to try the qualities of different waters for cooking and culinary purposes; you have probably used Thames water?—Yes, I have; when I first became cook to the Reform Club we occupied Gwydyr House, which was then supplied with Thames water.

What was your experience of it?—That it was very hard and inconvenient; it had sometimes a disagreeable taste; this, however, we found was occasioned by the cistern, which we remedied; it was, however, at all times very hard.

What was the effect of the hardness in cooking?—That we were in many processes obliged to use potass or soda for the water, to soften it.

What were the processes?—First, in boiling cabbage, greens, spinach, asparagus, hard water gives them a yellow tinge, especially in French beans: hard water shrivels greens and peas, and will be more particularly noticed in French beans; the process of boiling is also longer.

That requires more fuel?—Certainly.

What would be the difference in time?—With dry vegetables certainly one-fourth more.

How is it with potatoes?—I do not think it acts so much upon potatoes, but still it has an influence upon all sorts of vegetables. I do not see the same effects however upon roots generally as upon leaves generally; the effects are very powerful.

What do you find to be the effect of hard water upon the animal foods?—Upon salt beef the hard water is not so good, it does not open the pores of the meat so freely as soft water. On fresh meat it likewise has a prejudicial effect, but not equal to that on vegetables. It has the effect of making very white meat whiter than the soft water; upon all delicate things it has however a more marked effect—for example, in making beef-tea, chicken or veal broth, or upon lamb; and the more delicate a substance is the greater is the influence of a hard water upon it. A hard water as it were compresses the pores, whilst a soft water dilates them and the succulent matter which they contain. It makes them more nutritious. The evil of hard water is more visible in small quantities, such as broth or beef-tea.

Then it will be the more prejudicial or expensive in domestic cookery, which must be in small quantities?—Exactly so; in the larger operations, where there is much boiling, the boiling itself, and for a long time, reduces the hardness. In the small quantities requisite for invalids and delicate persons the disadvantages are the most experienced. When I used Thames water at Gwydyr

House, I have had quantities boiled in order to soften it, and have then let it get cool and kept it ready for use for the smaller operations.

What is the effect of hard water upon bread?—I have not had practical experience in bread-making; but there is not the least doubt that soft water is of the greatest importance as making the best bread. This is exemplified in Paris, where the water is hard, and where that bread which is made in imitation of Gonness bread, though made with the same flour and by the same bakers, never equals that made at the place itself, where the water is soft. I am informed that part of the water at Glasgow is very soft, and that the Scotch bakers from thence, when they first come to London, cannot understand why the bread does not rise so well as in Glasgow, even though they make use of the same yeast and flour. It is well known that the addition of a small quantity of bi-carbonate of magnesia in the water renders bread lighter and whiter.

What is your experience in respect to tea?—The hard water is injurious in deteriorating the flavour; it also requires more tea to give an equal strength. There can be no doubt that the softer water is of very great importance; we have found it so with the water used at the Reform Club, which is Artesian well water.

In respect to coffee, what is your experience?—Hard water produces a similar effect, but not quite so powerful.

[The witness was requested to obtain more particular or closer proximate results as to the comparate value of Thames and the Artesian well water in making tea, taking into account flavour as well as strength of extract.]

Have you made the examination as to the comparative effect of waters of different qualities in the preparation of tea?—Yes, I have. In making the experiments, as time is of importance for the effect as well as for economy, I thought it proper to take an account of it. For culinary purposes I am confident that that water which boils the quickest is the best; and I conceived that this might be ascertained in respect to tea. I took samples of the common tea in use by the population, green tea and tea of a third class, and prepared them with equal quantities of water: I took, as the standard of soft water, distilled water, which I obtained from Apothecaries' Hall. The whole results were more striking than I had previously anticipated. The softest or distilled water had an extraordinary power in obtaining a quick extract; the result showed perhaps too high a power, for it draws out the woody flavour. Next to it was the Artesian well water, which is one-third less hard than the Thames water. I should indeed prefer that water to any other tried in these experiments: although the distilled water draws out the aromatic property of the tea more than the Reform Club water, it does not I think produce so good an extract. Each water gave its own shade, and had its own distinct extract. Finding the results so extraordinary,

I solicited the assistance of two friends, Messrs Hooper, the most eminent tea-tasters in London: the results were the same, and the following table gives the conclusions I came to:—

Kinds of Water.	Time taken to boil.	Their rank in making of Tea.	REMARKS.
Distilled water from Apothecaries' Hall	Min. 5½	2	
Covent-garden, an Artesian well*	8½	5	* Impure as if it contained iron.
Reform Club, 360 ft. deep,† and Trafalgar-square	6½	1	† This well has been sunk ten years; the pipes are the same as at first laid down, but they are all blistered. This makes tea one-third more than any other water.
Camden Town, sunk 200 feet in the chalk‡	8		‡ This is the well sunk by the North-Western Railway Company for the supply of their locomotives. I moved the machinery for manufacturing the nectar into Whittlebury-street, close to Euston-square Station, in order to receive the advantages of this water, and paid a large sum per annum to the Company to obtain it; but I find that the water, in passing through the iron pipes from Camden Town to the station, becomes so impregnated with iron as to cause it to be considerably altered in its nature. This fact may be seen by the deposit of iron it leaves at the urinals in the station: it likewise makes deep grooves in the pipes, as if planed out with a machine.
New River, from a cistern in Billiter-street, City	8	3	
Wellclose-square, a spring	10		
Camberwell, a sunk well 60 feet deep§	10		§ Camberwell is considered the hardest water in the vicinity of London.
Thames, from Hungerford, 2 hours after high water	9½	4	
Standard solutions of lime-water, reckoned according to Clark's scale of hardness:—			‖ Of the three No. 2 is by far the best.
2°‖	7	6	¶ Very impure, and boils with a scum upon it.
8°	7½	7	
16°¶	8½	8	

Are you confident as to the difference in the time of boiling between hard and soft water?—My experiment was with pints of water, in the same size stewpan, with a gas lamp, so that the heat was manageable, and the same in both cases; and there was certainly a difference of full two minutes in favour of the boiling of the soft water; and the same result was given in several experiments.

From these experiments, and your extensive knowledge, will you state the general results as to the relative power of the hardest and the softest water in making tea?—I should say that whilst with

the hard water three cups might be made, with the soft water about five might be made.

What extra expenditure of tea then would the use of the Thames water incur in making tea?—Nearly one-third.

That is on all the tea consumed in the metropolis?—Yes, I have no doubt of it.

Do you consider that the action of water in tea is a fair test and representative of its action on meat and vegetables in general, in all the delicate processes of cookery?—Yes, I do; and I have proved it in the following way. I have taken the solution of 16°, and compared it with the water from the well of the Reform Club. First, with vegetables, that is, carrots, turnips, and onions, cut into small pieces of about one inch long and an eighth of an inch square, such as are used in Jullienne soup, placed in two saucepans, with the same quantity of water, and on the same gas-stove: those cooked in the Reform water were quickly done, and the flavour of the vegetables in the water; whilst those cooked in the solution never became tender, nor did the flavour go into the water. Secondly, with potatoes: I cut a peeled potato into two, and boiled them at the same time in the above waters; the difference was easily distinguishable, that which was boiled in the hard water being harder, but at the same time whiter. Thirdly, in extracting the juice or gravy from meat: the soft water does so quickly and well, but the hard water, instead of opening the meat, seems to draw it closer together, and to solidify the gluten, and I believe that the true flavour of the meat cannot be extracted by hard water. In boiling of salt meat less salt is extracted when boiled in hard water, and at the same time the meat is not so tender as when boiled in soft water. Soft water evaporates one-third faster than hard water. I should, in every way, give the preference to soft water, but, at the same time, if very tender meat is required to boil very white, hard water should be used.

We directed the attention of Mr. Philip Holland to the subject, as he had had under his consideration the improved soft water supplies gained for some of the towns in Lancashire. He was asked:—

Have you tried the difference of hard and soft water for cooking?—I have not made any accurate experiments except as to tea-making; I find that the water softened by means of oxalate of ammonia extracts the strength of tea almost twice as well as when hard. I had tea made with equal quantities of the leaf and equal quantities of boiling water, with and without oxalate of ammonia. The infusion made with water softened by the oxalate was strongly and better flavoured, and had to be diluted with the addition of 80 per cent. of hot water to bring it down to the strength of the

other. It follows, therefore, that with the oxalate 10 parts of tea go as far as 18 without it.

Does that saving pay for the expense?—Over and over again; my tea costs me about 1*s.* a-week: if I can save eight parts out of 18, I can have as strong and better flavoured tea for less than 7*d.* a-week, being a saving equal to half the water rate. It is not easy, however, to get these savings effected regularly, it is apt to be forgotten, and cannot well be left to the servants. It would be far better to have a water originally soft, if it were procurable.

The attention of Professor Clark having been directed to this subject, he made the following answers to our enquiries:—

My health has, heretofore, prevented me from making any more than merely preliminary experiments. From these it appeared that hard water was very unfit for the purpose of infusing tea. In making use of a series of waters at 4°, 8°, 12°, 16° of hardness, the strength of the infusion, as manifested by the depth of colour produced, was evidently in a series, such that each infusion could be sensibly distinguished from the one next to it, above or below, the hardest water giving the least depth of colour, and the softest water the greatest. At 4° of hardness the infusion was transparent with no sensible muddiness; at 6° the transparency of the infusion began to be injured; at 12° there was a distinct muddiness; at 16° this muddiness had become very decided, and above 16° it was disgusting. No such muddiness appeared with any of the waters after pouring off the first infusion and making a second. With regard again to depth of colour, it is very worthy of remark, that whereas the greatest depth was observed in the first infusion in the softest water, and the least depth in the hardest, now, in the second infusion the same thing was observed again, with this difference, that in the harder waters the depth of colour was proportionally still less; not only absolutely less, as might be expected, but relatively less. In making these experiments, about half an ounce of tea was made use of with a pint of boiling water, so that you will understand the result if you suppose in each of two similar teapots half an ounce of tea be put, and over each a pint of boiling water, but in the one case at 4° hardness, and in the other case at 16°; the infusion at 4° will turn out much stronger than the infusion at 16°; the infusion at 4° will be transparent; the infusion at 16° will be offensively muddy. But supposing you pour off the first infusion and make a second infusion, then the second infusien at 4° will be a little weaker in colour than the first infusion at 4°, while the second infusion at 16° will be of a still proportionally weaker colour than the first infusion at 16°. In short, hard water is bad for a first infusion, still

worse for a second. The only way of making an infusion of tea with waters at 8°, 12°, or 16°, equally strong with an infusion by water at 4°, is to increase in each case materially the quantity of tea infused. Sub-carbonate of soda in crystals may be made use of in very small quantities in order to soften the water and make it fitter for the purpose of infusing tea; it produces this effect by decomposing the earthy salts present; but if made use of in any proportion above what will exactly decompose the earthy salts present, the excess may, indeed, deepen the colour of the infusion by dissolving some coloured vegetable extract such as pure water would not dissolve, but it will infallibly injure the fine flavour of the tea to all persons not accustomed to the taste of soda in their tea.

The fact elicited in the examination of Mr. Soyer, that water which readily extracts the strength and flavour of tea is generally equally good for all culinary operations, has appeared to us to be so important, that we have had it under consideration to direct the trial of waters for the use of a town by tea as well as by a soap test; an experiment which is now under extended trial.

Next to the importance of softness, or the detrimental effects of hardness in all the culinary operations of the population, are the waste and inconvenience which hardness occasions in washing the person and in washing clothes. It is proper to submit a view of the aggregate magnitude of the operation of washing clothes, for which suitable water is required for the use of the population of the metropolis.

If the importance of what is politically called an "interest" be measured by the aggregate amount of the expenditure involved in it, then the washerwoman's interest is larger than the chief manufacturing interest of the country—the cotton and linen manufactures,—(at least as far as the home market is concerned)—inasmuch as far more money is expended in washing clothes than in the manufacture of the fabric or of the clothes themselves. To take the instance of the shirts worn by a labouring man: the following is the account given of the cost of a cotton shirt, manufacture, material, and making, as given by a manufacturer in Lancashire:—

Working man's shirt, strong calico, of four yards, costs bleached 2*s*., grey 1*s*. 10¾*d*.

Material.—Cotton at 6*d*. per lb.;		*d.*
1¼ lbs., with loss thereupon . . .		8·25
Manufacture,—	*d.*	
Spinning	2·25	
Weaving	3	
Profit	·25	
		5·50
		13·75
Bleaching about		1·25
		15*d*.

Grey 13·75 *d.* + 9*d* (making) = 1*s*. 10¾*d*.

Bleached 15*d*. + 9*d*. = 2*s*.

Now in London the charge for washing the shirt would be 3*d*. each time,* and it would be washed probably 40 times before it was worn out; that is to say, it would have cost in round numbers ten shillings for washing. Before it is worn out, five times as much money as it originally cost will have been expended upon it in washing.

To take another example of a person in middle class life:—

---

* The following is an extract from the Manufacturer's letter on the expenses of washing in the North of England:—

"I find that with the labouring classes here one shirt is generally washed each week, and they last from 9 to 10 months. The above prices are rather above the rates of the last two years. The apportionment will vary with the fineness of the calico. The material being less costly and the manufacture more so, as the cloth is finer, one nearly balancing the other. As to washing, I include labour, soap, fire, and a trifle towards a larger rent. I have inquired of many, and I find that the expense of washing varies inversely as the quantity—from one-third to two-thirds of a penny for each separate article. As a shirt would take much more washing than most things, it cannot be taken to cost less than 1*d*. each washing. Thus the shirt would have cost 2*s*., and the washing of it 3*s*. 6*d*. As a specimen, one person's information is something like this:—

	s.	*d.*
Labour of a woman, 1½ days	1	6
Soap, 1 lb.	0	5
Fire	0	4
Rent and utensils	0	3
	2	6

This woman washed above 70 articles."

A dozen of strong linen shirts cost fourteen shillings each, of which four were worn and washed each week. They were worn out in eight years: they had each cost for washing 2*l.* 0*s.* 5⅓*d.*

The expenditure by families of the middle class in washing amounts often to nearly one twelfth or one thirteenth of their income. We find that the expenditure of a number of middle class families for washing, in the metropolis, rarely falls short of one-third of the amount of their rental.

The *proper* expenditure by an adult of the labouring classes would be about the regular expenditure for a male or female servant, namely, from 1*s.* to 1*s.* 6*d.* per week. Too many of the labouring classes do not expend such an amount, either upon themselves or their children; but the present expense and inconvenience of this important sanitary operation is the great obstruction to its due performance, by the present distribution of water, and that expense is materially augmented, as will be seen, by the waste of soap occasioned by hard water. This waste, amounts to 25½ ozs. of soap in the use of each 100 gallons of water of 16 degrees of hardness, over and above that which would be required with a water of 4 degrees of hardness; or, with the price of soap at 5*d.* the pound, causes an extra cost of 8*d.* on each 100 gallons, or 6*s.* 8*d.* on each 1000 gallons; being more than 20 times the first cost of an economic water-supply, as furnished in several towns, or as might be furnished to the metropolis, allowing 7½ per cent. for the use of the capital required.

Mr. Donaldson, the agricultural surveyor, who has paid attention to this subject, estimates the saving as follows:—

"From several analyses and calculations," he says, "as to the saving in soap by the use of soft water; and from inquiries I have made of numerous consumers, of the quantity of soap used per individual, it appears that for every 100 gallons of water used in washing, two ounces of white curd soap is required for every degree of the hardness of the water used.

Thus a water of 5 degrees hardness takes . 10 ounces of soap,
And one of 15 degrees hardness takes . . 30 ,,

I find that 14 lb. per individual per annum is about the average consumption of yellow soap for washing and domestic use, and

the price is about 5*d.* per pound. Therefore 100 individuals using water at 15 degrees hardness take 1,400 lb. of soap at

5*d.* per lb.	£29	3	4
And with water 5 degrees hard, 466 lbs. .	9	14	3
Difference .	£19	9	1

In round numbers the saving in soap by using water 5 degrees hard instead of 15 degrees is 20*l.* per 100 individuals, exclusive of the tear and wear of clothes from washing in hard water which will fully equal the saving in soap."

On the whole, from such information as we have been able to collect, 1*s.* per head per week on the population of the metropolis, appears to be not an extravagant estimate of the general expense of washing, making, however, a certain deduction for the known neglect of washing by the labouring classes.

Mr. John Bullar, the Honorary Secretary to the Association for the Promotion of Baths and Washhouses, has arrived at the same conclusion, on the following data :—

In the year 1844, when "The Committee for promoting the establishment of Baths and Washhouses for the Labouring Classes" was formed, it was deemed advisable to ascertain, as accurately as possible, the actual washing expenses of labouring men and their families whose washing was done at home. Inquiries were, therefore, made of several hundred families of labouring men, and it was found that, taking the wife's labour as worth 5*s.* a-week, the total cost of washing at home, for a man and wife and four children, averaged very closely on 2*s.* 6*d.* a-week = 5*d.* a-head. The cost of coals, soda, soap, starch, blue, and sometimes water, was rather less than one-third of the amount. The time occupied was rarely less than two days, and more often extended into a third day, so that the value of the labour was rather more than two-thirds of the amount.

I may mention here that the average time occupied by a woman in washing and drying her family's clothes at the Model establishment of Baths and Washhouses, Goulstone-square, Whitechapel, and the St. Martin's-in-the-Fields Laundries, is about two hours and a-half, and the payment for that time, which covers the expense of coals and water, is 3*d.*; so that already (for such establishments are but in their infancy, and are capable of considerable improvements), the 2*s.* 6*d.* a-week may be considered as being reduced at least one-half to those who avail themselves of the washhouses.

In the course of the two succeeding years I made inquiries, as

opportunities offered, of the cost of washing to single men among the labouring classes, whose washing expenditure might be expected to be on a very low scale, such as hod-men and street-sweepers, and I found that the lowest average weekly cost of washing to such of them as could reckon it, was 4½*d.* a-head.

I found it very difficult to ascertain the cost of washing to very small tradesmen; but I came to the conclusion that it could not be safely estimated at much more than 6*d.* a-head a-week. Many of them maintain a position of solvency only by the narrowest economy, and it is probable, not only that their expenditure for personal cleanliness exceeds but little, if at all, that of mere labourers, but that they as rate-payers have a direct personal interest in the establishment of parochial washhouses. The Rev. Sir H. R. Dukinfield, who was intimately acquainted with the condition of his (late) parish, St. Martin's, was so strongly impressed with this being the case, that he suggested the first class washing-places for them which have been provided in that parish.

It may, perhaps, be safe to reckon the weekly washing expenses of the poorer half of the inhabitants of the metropolis at not exceeding 6*d.* a-head; but the expenditure for washing rapidly increases as the inquiry ascends into what are called the "middle classes." Among them various sums, from 9*d.* to 1*s.* 6*d.* a-week a-head, are allowed to maid servants for their washing, and besides that allowance, they very commonly wash at home small articles, such as caps, collars, &c., for themselves, and not, I apprehend, with any very strict regard to economy of fuel, soap, &c. The weekly allowances for washing to men servants range, I believe, from 1*s.* to 2*s.* 6*d.* a-week, and a little washing at home is not unfrequently done for them.

It is, perhaps, safe to consider the washing expenses of the families in which those servants are employed as double that of the servants, and, therefore, as ranging from 1*s.* 6*d.* to 5*s.* a-week a-head. In many of the wealthier families it is much higher. I have found the weekly washing-bills of young men living in chambers to range from 3*s.* 6*d.* to upwards of 10*s.* a-head.

You will easily imagine the difficulty of ascertaining with any exactness the washing expenditure of private families, and my consequent necessity of making a rough estimate. The conclusion at which I arrived was, that, taking the whole population, the washing-bills of London were nearly 1*s.* a-week a-head, or 5,000,000*l.* a-year. Your objection that "that was half the rated rental of the metropolis," has tended to confirm me in that conclusion.

The rated rental of a house occupied by a labouring family, whose weekly washing expense is 2*s.* 6*d.*, is probably rarely equal to 5*s.* a-week. Where such a family occupy a part of a house, the proportion of that rental attributable to their rooms, or their single room, is probably decidedly less than 5*s.* a-week, except in

peculiar cases. It is, therefore, not improbable that the yearly washing expenses of the poorer half of the inhabitants of London are quite equal to one-half of the rated rental of their dwellings.

The washing expenses of a middle-class family, inhabiting a house rented at 120*l*. a-year, and rated (high) at 100*l*. a-year, consisting of husband and wife, three children, and three servants, may be taken at not less than 20*s*. a-week, or more than half the rated rental; and from all that I have been able to learn, the proportion which washing expenses bear to rent is much greater in those families whose income is large enough to free them from the necessity of studying economy in matters of ordinary domestic expenditure. It is said that the average yearly value of the houses in London assessed under the Income Tax is 40*l*.; and that the average number of persons to every inhabited house in London is 7·4. At 1*s*. a-week a-head the washing-bills of the persons inhabiting each of those houses would be within a very small fraction of 20*l*. a-year.

Whether you take 1*s*. a-week a-head for all the inhabitants of the metropolis, or one-half of the rated rental of its houses, the washing-bills come, in round numbers, to 5,000,000*l*. a-year. Of course I give this as but a rough estimate, and many exceptions may easily be taken to it; but I feel pretty confident that it is not very far from the truth.

We have received evidence which proves, that in some of the first class private families in London the washing bills amount to 400*l*. per annum. In one large hotel establishment it amounts to 2,000*l*. per annum. Whether, in the metropolis, the sum of 5,000,000*l*. a-year be actually expended for washing or not, any deficiency in this estimated exdenditure, if such deficiency really exist, must arise from the neglect of washing by the labouring classes.

Though the expense of soap in washing is a minor item of the total expense, it is yet a very serious one; and the effect of hard water is experienced in the wear of the linen, as well as in the extra expense of soap. On this point Professor Clark observes—

With regard to the softness of water, this quality is of importance, not merely for the saving of soap to households, for the agreeableness of washing at the toilet, for the agreeableness and utility of bathing, which I account a most important practice for promoting the health of the inhabitants of a town, but also in respect of the wear and tear of linen due to hard water. Such

wear and tear comes to be a very large item of expense to the inhabitants of a town. The inhabitants of London are probably not aware so much as visitors from the country are, of the amount of destruction to clothes in consequence of the hardness of the water, and the use of soda in order to get rid of the hardness. I remember an occasion, which I may mention, where the amount of wear and tear was brought out in a very conspicuous manner. Two young men, brothers, in Glasgow, were put into counting-houses, one in London and the other in Glasgow. They had each a similar assortment of shirts given to them. Some time after when the brother in London came back on a visit to Glasgow, the lady of the house pointed out, to the wonder of her female friends, the difference there was in the wear of the shirts of the two brothers, that had been given at the same time; those that had undergone the London washing were so much more worn than the others which had been washed at Glasgow. Yet I can state from experience that linen gets soiled from the atmosphere rather more readily in Glasgow than in London.

What was the difference in the hardness of the water?—The hardness of the Glasgow water was about 4°, and that of London about 12°.

It is to be assumed that a great saving would accrue to a town by using soft water, in the article of soap, for instance?—Not only in the article of soap, but probably much more in the saving of the wear and tear of clothes. The hard water has a tendency to discourage washing of clothes among the poorer classes, and to bring on them greater expense in clothes. This consideration bears very closely on the clothing of women and children; and I rather think, that if manufacturers of the articles of clothing worn by women and children, in a district supplied with hard water—this very London, for example—were consulted, it would appear that they are obliged to supply articles of such dark dyes as will not let the dirtiness be seen. Now to substitute the art of concealing dirt for a habit of cleanliness, not only is unfavourable to health and comfort, but is unfriendly to a decent self-respect; yet an observant eye cast on the women and children of the poorer inhabitants of London may discover that such has been the result here.

Do you know what relation the cost of soap consumed in London bears to the gross water-rent?—I reckon the cost of soap consumed in London to be about double the gross water-rent. The quantity of soap consumed in England, Wales, and Scotland can easily be ascertained from official returns. From these the consumption of every individual of the population appears to be nearly 7½ lbs., or 120 ounces, which, at 1*d.* for three ounces, or 50*s.* per cwt., comes to an expense of 3*s.* 4*d.* for each person. There are no official returns from which to give the consumption of soap in

London alone; but after making diligent inquiries as to the consumption of soap in families that washed on their own establishments, and obtaining what I believed was the best information that the trade could afford, I came to the conclusion that the average consumption of each person was about double in London what it was over all Britain—that is to say, 15 lbs., which comes to 6*s*. 8*d*. for each person. It is to be remembered that London is a hard-water district. The Commissioners must be aware that there are at present no very accurate data for an estimate of the water-rent paid by each person in London, but 3*s*. 4*d*. seems as accurate an estimate as can now be made. Thus 10*s*. for each person is the cost of soap and water in London; 6*s*. 8*d*. for soap, and 3*s*. 4*d*. for water. Since the soap costs twice the water, whatever be the rate of saving on soap, that rate will become twice as much when reckoned on the water. For example, if the saving by softening the water be only 5 per cent. on the soap, it would be 10 per cent. on the water.

What is the total soap used in London?—About 1,000 tons a-month, at about 50*l*. a ton, and along with it is used about 250 tons of carbonate of soda, at about 10*l*. a ton, costing together 630,000*l*. a-year.

Mr. William Hawes, who has for some years conducted a large soap manufactory, gives a lower estimate of the actual quantity of soap sold in the metropolis, which is, 800 tons per month, at 45*l*. per ton. It must at the same time be observed, that a proportion (probably a large one) of the clothes worn in the metropolis are washed at places some distance from it.

Mr. Philip Holland, having recounted an invention of his for applying Professor Clark's process on a small scale—which appears to be well deserving of attention for the hard-water districts, was asked—

After the liming and filtering, is the Lambeth water a first-class water?—Certainly not, far from it. It is still hard, though much less so than before; neither is it so pleasant to drink as the bright sparkling mountain water with which Manchester, for instance, is to be supplied. Nevertheless, it is not much to be complained of, and I have good reason to be grateful to Dr. Clark for showing so easy a way of improving it so much.

Can you not improve the water still more?—Yes, for washing, by adding to it a little oxalate of ammonia or of soda. I use the former. This precipitates all the lime, and makes the water very soft.

Do you consider it worth while to take all this trouble, and to incur this expense for the sake of soft water?—Certainly, it is

very well worth while; in fact, without liming I consider the water quite unfit for drinking. Though it varies in quality it has generally a very perceptible taste and smell which the lime removes. Then, as to softness, I am charged 44*s*. a-year for water (which is far too much), but, however, water costs me say 10½*d*. a-week, but the soap for my family, in addition to that for the washing sent out, costs about 1*s*. 6*d*. a-week, or nearly twice as much as the water. It is evident that by diminishing the hardness of the water, and thereby the waste of soap, I may easily save the amount of my water-rate in that article alone. Besides that I can wash comfortably with the softened water, but I cannot do so with any quantity of soap with the water before it is limed, unless I have it boiled to precipitate the chalk, which process is more expensive and troublesome. I should, however, much prefer being supplied with a water fit for ordinary domestic purposes, and, if necessary, paying more for it, though I think the present charge exorbitant, even if the water were good, but outrageous considering the stuff with which they supplied me.

At Bolton, where a change was made from water of about five and a-half degrees of hardness, or one-third of the hardness of Thames water, to a water of about two degrees of hardness only, the reduction of the expense of soap and ashes for washing at the Bolton Union workhouse, was found to be on the average of 13 weeks, from 2*l*. 10*s*. 1*d*. before the change, to 1*l*. 11*s*. 10*d*. per week with the purer water.

Of the fairness of the estimate of the expense of washing to the higher and middle classes, and to the great bulk of the householders, and the better class of artizans, we entertain no doubt whatever. Whatsoever deductions, if any, may be made from the above estimate, it is, nevertheless, an under-estimate for maintaining, at the present expense of washing, a proper amount of cleanliness in linen.

The extra cost incurred by the use of hard water shown by the chemist is demonstrated in domestic practice. A lady recently come to reside in London has found the following difference in the quantities of soap and soda required to wash the clothes of the same household. In the country rain water was used; in London water from the Chelsea Water Works is used.

COMPARATIVE COST.

Material and Labour.	Country with soft water.	Town with water from Chelsea Water Works.
	s. d.	s. d.
Soap . . .	½ lb. at 6*d*. = 0 3	1½ lbs. at 6*d*. = 0 9
Soda . . .	¼ „ 1½*d*. = 0 0⅜	1¼ „ 1½*d*. = 0 1⅞
Labour, say .	5 0	10 0
	5 3⅜	10 10⅞

The difference does not, however, end with the additional cost in material and labour, inasmuch as the hard water requires twice the time, which is probably the greatest tax and inconvenience, as the whole house is disturbed during the process; but beyond this there is the additional wear and deterioration upon all clothes, especially those of a fine texture, such as muslins and cambrics. The destruction of these is doubled by hard water; so that if five shillings represents the cost of washing a certain amount of clothes with soft or rain water, four times this sum, or one pound sterling, will be the cost of using hard water, such as the Chelsea Works supply, namely, 16 degrees of hardness, according to Dr. Clark's soap test.

It is stated, however, by the practical witnesses, that there is an advantage in soft water not to be obtained by any amount of labour or expense from hard water, short of distilling it, namely a certain quality of cleanliness and purity is imparted to all clothes by soft water, in part from an almost entire absence of alkaline or mineral ingredients, which does not fully leave clothes washed in hard water.

Laundresses and persons carrying on the business of washing, on a large scale, near London, complain that the water as delivered is turbid, and discolours the linen.

The following is stated as an example:—

"The Manager of the Steam Laundry Old Kent Road (Mr. Krantz) stated that, when he first undertook the works, he found that the water supplied was on the intermittent system, and that it was delivered every day; but that, when the daily supply came in, the water in the cisterns was rendered so turbid by the

residuum in the tanks being stirred up, as to be totally unfit for properly rinsing the linen; and that, in consequence, numerous complaints were made by his customers as to the bad colour of the clothes washed. He, therefore, applied to the Kent Waterworks Company to have a supply constant and at high pressure. After some considerable objections on the part of the Directors his desire was granted on the condition that he should pay the expenses of laying the water on direct from the main, and that his charges be raised cent. per cent. He, although considering the terms exorbitant, felt that he had no option, if he wished to retain his business, and, therefore, consented to these high charges. The result is that, notwithstanding this heavy amount of charges, he finds that he can do much better than before."

It is here proper to observe, however, that the linen worn by the labouring classes, in the poorest, worst cleansed, smoky and sooty neighbourhoods of manufactories, is dirtied much more rapidly than in other districts; and that common observation of the rate at which the skin, linen, and clothes (not to speak of paper, books, prints, and furniture) become dirty in the metropolis, as compared with the time that elapses before a proportionate amount of deterioration and uncleanliness is communicated in the rural districts, or even in many of the provincial towns where there are no manufactories, will warrant the estimate, that full one-half the expense of washing to maintain a passable degree of cleanliness, according to the existing habits, is rendered necessary by the excess of smoke generated in open fires, and the excess of dust arising from the imperfect scavenging of the roads and streets. Persons engaged in washing linen on a large scale, state that, it is dirtied in the crowded parts of the metropolis in one-third the time in which the like degree of uncleanliness would be produced in a rural district. But they all attest the fact, that linen is more rapidly destroyed by washing than by the wear on the person. The expense of the more rapid destruction of linen must be added to the extra expense of washing. To reduce the general nuisances by which these expenses and inconveniences are occasioned,—nuisances the greater portion of which are due to local maladministration, and which occasion an extra expenditure of upwards of two to three millions per annum, (exclusive of the injury done to

the general health and the medical and other expenses consequent thereon,) an equivalent expenditure, or a rate of about 2*l.* 10*s.* per house per annum would be warranted.

We shall subsequently show that improvement in pavements and the application of water to the surface-cleansing of streets, may be made the means of effecting a considerable reduction of the existing expenses occasioned by excessive uncleanliness.

Impressed with the great importance of the examination of the qualities of the water supplied to the population, we have, wherever the application of the Public Health Act was under consideration, endeavoured to impress upon our engineering inspectors the necessity of careful searches, with the view of securing, in the highest degree, the quality of softness. The qualities for the water supply of the population appear to us to range themselves in the following order:—

1. Freedom from all animal and vegetable matter, especially matter in a state of decomposition.
2. Pure aeration.
3. Softness.
4. Freedom from earthy or mineral, or other foreign matters.
5. Coolness in delivery, at a medium temperature neither warm in summer nor excessively cold in winter.
6. Limpidity or clearness.

As popular tests, it is agreed that all special flavour or taste in water is objectionable, as denoting the presence of foreign matters; that the water in which the slightest smell is perceptible, should be rejected usually as tainted with organic matter in a state of decomposition, or some insalubrious mineral matter; that water which has the slightest shade of colour should not be used without filtration, as it usually contains earthy or vegetable matter. In addition to these tests by the senses, and of the taste by freshness, denoting good aeration, though without the briskness of carbonic acid gas, the soap test may be used.

G

We have directed searches, to greater distances than usual, for sources of water with these requisites. Where waters with these essential qualities have not been found, we have directed attention to the means of obtaining them artificially.

In the chalk or hard water districts, where no soft water was available, within any distance now deemed practicable, the engineering Inspectors have in several instances, recommended the adoption of Professor Clark's process on a large scale, as a means of amelioration. The importance of a natural purity of quality appears, however, to be so great, as to justify much additional expense to procure it for any town, but this importance increases with the magnitude of the population to be supplied.

Taking into account all the considerations in respect to the qualities of a water, for the supply of a town population, and the facts and the concurrent testimony of competent and disinterested witnesses, and evidence of different towns and places:—

We must state as our conclusions upon this topic of inquiry, that if the water of the Thames could be early protected from the sewerage of all the towns draining into it, and from the sewerage of the metropolis—if it could be purified from animal and vegetable matter as completely as deep well water, or as some of the surface water from the chalk districts, as proposed by Captain Vetch, we should nevertheless feel compelled, upon the evidence recited, to pronounce water of such degrees of hardness to be ineligible for the supply of the metropolis, and to recommend as we now do,—

That the water of the Thames, the Lea, the New River, the Colne, and the Wandle, as well as that of the other tributaries and sources of the same degrees of hardness should be as early as practicable abandoned.

Being convinced that the great inconvenience and expense attendant on the use of the present supplies of hard water will justify a considerable outlay in obtaining supplies of a purer and softer kind, untainted with animal, vegetable, or mineral pollutions, and

anxiously impressed with the importance of this object, when Dr. Angus Smith had completed a satisfactory examination of the Thames from its source, we made early application for the aid of the officers of the geological survey, in an examination of the surface soil, and strata of the country around the metropolis, with a view to ascertain the qualities of waters derived from the rain-fall taken nearer the sources than the common river supplies. In the mean time, and with views which we now proceed to submit, we pressed forward, at every opportunity, our own direct investigations, in extension of those of which the results are given in the Second Metropolitan Sanitary Report, displaying the state of the marsh lands in the neighbourhood of the metropolis, and the necessity of extensive suburban land drainage (*vide* Report of Mr. Donaldson).

We may premise, as a truism, that the quality of rain water will depend on the nature of the geological stratum and the condition of the surface on which it falls. Whatsoever soluble organic or inorganic matter there may be, either on the surface or in the substrata, the less time the rain water remains there, or the less the extent of surface which it washes, or the less the distance of the substratum through which the water percolates, the less in general will be the amount of matter which it will take up. The River Thames and its tributaries, which are largely derived from land springs through chalk strata, are varied in quality by the surface flood waters. The presence of these surface flood waters is made known to the population by the particularly turbid state in which the water is delivered. Much of this turbidity is occasioned by animal and vegetable matter so completely in chemical solution, that, as several witnesses have stated, the common strainers or filters will not remove it. It is also the complaint of agriculturists, that much of the manure applied to the land, as well as the finer particles of soil, are swept away by heavy rains into the ditches, and natural water courses. The deposit of surface particles of inorganic, mixed with a large proportion of organic matter,

detained by the filtration of Thames water from above Battersea, amounts, in the reservoirs of the Vauxhall Company, to more than a foot in depth per annum. Mr. Bowie states, that in the water of the River Lea, which he received into his own house during the potato disease, he distinctly perceived the peculiar smell of that disease, and that it was much noticed by other persons. This result was no doubt produced by the flow of the surface waters from tracts of land laid out in potatoes, and presents an example of that infusion of vegetable matter and manure, which from the absence of any peculiarity by which it may be detected is generally unnoticed.

Deep well water is free from these surface animal and vegetable impurities, but it has generally more of mineral impurity, and is usually unattainable in sufficient quantity at a moderate expense.

Seeing the disadvantages inseparable from river and well-water, attention has been directed to other sources of supply. The necessity of purer water for some manufactures has led in the north of England to material improvements in its collection, storage, and delivery. Professor Clark, states as the result of his observation on the supplies of towns, that nowhere have there been made such important improvements in the collection and purification of water supplies as in Lancashire.

The improvement in the collection is due to the application of the principle we have above stated, that is to say, that the nearer to the actual rainfall the water is collected, the freer it will be from adventitious impurities. The new practice in Lancashire, has been to take some elevated ground, generally sterile moor-land, or sandy heath; and to run a catch-water trench or conduit round the hill, midway, or as high up as may be convenient for the sake of fall, regard being had to the space of the gathering ground. An embankment is thrown across some natural gorge, at the nearest point at which a reservoir may be formed without the expense of excavation. Into this the rain

water is led and stored to be used in dye or print works, or for other manufacturing purposes, having in many instances been previously filtered.* The economy and efficiency of these filters which merely act as strainers, are much praised by Professor Clark. They serve to show, however, how much more economically filtration may be conducted on a large than on a small scale, and how sordid and erroneous is the administration, whether of water Companies, or local Boards, which neglects or refuses filtration of the supplies used for the general population. But until recently, with the exception of a very small proportion, the supply of towns was delivered without any previous filtration whatsoever, and more than half the supply of the metropolis is still so delivered. Glasgow, Paisley, Kilmarnock, and other towns in Scotland; Bolton, Bury, Blackburn, Stockport, and other towns in the north of England, are now supplied with soft water, derived from gathering grounds. For Manchester and Liverpool works for new supplies on that principle are in progress.

The observations already collected under the Public Health Act, of the comparative purity of different waters, appear to us to establish the axiom we have above enunciated, that the shorter the space of land which water has to traverse, or the shorter the time which it remains upon it, the less will be the quantity of adventitious impurities which it will imbibe. We have had 424 different specimens of water from different parts of the country tested, and we find, that in respect to hardness, the following are the results:—

1. Wells and springs (264 specimens), average hardness, 25·86.
2. Rivers and brooks (111 specimens), average hardness, 13·05.
3. Land and surface-drainage (49 specimens), average hardness, 4·94.

The new process of land drainage furnishes a means for the filtration and depuration of impure waters on a large scale, with considerable advantages over the larger sand-strainers or common filters. The new

* *Vide* Appendix, for an account of a filtering bed, such as those in use in Lancashire.

method of relieving land from surplus surface water, by drainage *through* the land, instead of *over* the surface, besides diminishing the injury to vegetation from the lowering of temperature by surface evaporation, and rendering the soil permeable to air, and thereby facilitating the processes of decomposition and assimilation, arises from this, that the particles of organic or inorganic matter, which may have been on the surface are carried down on the first fall of rain water, and lodged in the subsoil or amongst the roots, where they serve as food to the plants. On the first working of land drains—in land which has long been water-logged, there is often for a time a considerable discharge of loose matter, until the table of land drained has been brought to a good working condition. Then, where the drains have been tolerably well adjusted, the water from this deep drainage is seen running away perfectly pellucid. Where there happen to be two branch outfalls into one main, the one a branch outfall from mere surface-drained land, the other an outfall from thorough drained land, the water from the thorough drained land may be seen running perfectly limpid, whilst the water from the surface-drained land runs away turbid, and of the colour and consistency of pea-soup, from the inorganic or organic particles which it contains.

Incomplete as the investigations of this subject as yet are, still they suffice to show that this process of drainage through some soils, with or without vegetation, is capable of effecting more for the depuration of surface water than is practicable by the common sand-filters or strainers. Thus, water containing peat in solution is, by reservoir filtration, only deprived of the fibrous matter held in suspension, whilst, by filtration through land, it is rendered comparatively, and sometimes perfectly, pellucid. Mr. Cooper, the chemist, in speaking of filtration, thus adverts to this fact:

After describing the filter made of finely powdered glass and animal charcoal, he is asked :—

Are there not natural filters which do detain matter in solution? —Yes; for instance, water which is impregnated with the water draining from bogs, which is of a pale brown colour when taken

up in a glass, and looks like an infusion of tea when in the river, is rendered quite colourless by percolation through a stratum of sand and gravel, in which vegetation is going on; and whether the decolouration arises from the effects of vegetation, or from the peculiar composition of the filter or percolate, I am unable to decide; but I rather give credence to the effect of vegetation, seeing that no artificially constructed filter yet made will effect the object.

The satisfactory course of such investigations as the present, involving physical and chemical operations, is frequently obstructed by the want of pecuniary means to execute proper trial works, and engage competent superintendence. No public funds are deemed to be properly available as means for the attainment of this end, even with the prospect of effecting public economies on the largest scale; nor has Parliament, nor have persons engaged in local public administration, yet been made sensible of the extent of mere pecuniary economy that is to be accomplished by the economy of health and life.

Early in the investigation, it was proposed to the Directors of the College of Chemistry, that they should, by analyses, determine accurately what matters were taken up by rain water falling on the surface of the soil, and what quantities of such matters were left in the soil, or taken out of the water in passing through different sorts of soils, at different depths and arrangements of soils and drains—objects of great importance for agriculture as well as for the determination of the qualities of water, or the means of its depuration. The College declined to undertake such investigation, as being too special, and as requiring too much labour. Recently, however, the examination has been made, mainly with respect to agricultural objects, by Professor Way, the chemist of the Royal Agricultural Society, and with most important results. From his examination it will be seen that clays and loams have powers of chemical action for the removal of organic and inorganic matters from water to an extent never before suspected, and that it will be practicable to use agricultural drainage arrangements on gathering grounds as means of filtration and more complete purification of water on a larger scale than is at present accomplished. The fol-

lowing portions of his examination indicate those results of his researches which bear practically upon our own investigation.

Your experiments were made, as we understand, with substances dissolved, not merely mechanically suspended in water; the action you are describing is, therefore, different from ordinary filtration?—Totally different.

If, for instance, you were to filter a solution of caustic potash through pure sand, you would not expect the alkali to be arrested? —Certainly not; sand would merely stop any solid substance suspended in the water, in the same way that the paper filter of the chemist does. Although, even in the case of a sand filter, very minutely divided solid matter would be liable to escape.

Do you consider the effect to be due to surface attraction, or is it a chemical action?—I believe it to be purely a chemical action, and that the different alkalies are absorbed in the relation of their chemical equivalents or combining proportions.

You state that ordinary soils possess this power, whilst pure sand does not; to what ingredients of soils do you attribute it?—I have good reason to believe that the action is due to the clay contained in most soils. I have already stated that sand does not possess the power, whereas a clay, with which I have made many experiments, exhibits the property in a high degree.

Have you made any experiments to ascertain the extent of this power of soils, and can you state to what amount the abstraction of salts by such filtrations would occur?—I have made a great number of accurate experiments on this point with different soils, and with solutions of salts of ammonia, potash, soda, lime, and magnesia, &c., of various strengths. The method of filtration was not in all these cases adopted, although convenient; it is, indeed unnecessary to the success of the process; for the power of soils to unite with the alkaline bases is so marked, that you have only to stir up with the solution a quantity of the soil, allowing it afterwards to subside, and the clear liquid will be found either entirely free from the alkali employed, or sensibly diminished in strength. I find that an ordinary loam will absorb about $\frac{3}{10}$ths per cent. of its weight of ammonia, and about one per cent. of potash, and so on for the other compounds of which we have been speaking. This quantity appears small, but it is in reality enormous, when the weight of a given area of soil is considered. Thus, for instance, the soil of an acre of land one inch deep will weigh about 100 tons, or 10 inches in depth 1,000 tons. This quantity of soil would therefore arrest and combine with three tons of ammonia, or 10 tons of potash. To furnish three tons of ammonia, 15 tons of sulphate of ammonia, or nearly 20 tons of Peruvian guano must be employed; so that I am justified in saying that this property of soils is, practically enormous.

To what extent does the separation of carbonate of lime by

filtration go?—Under the most favourable circumstances, that is to say, by stirring up the materials, so that every portion of them should come in contact, I find that 100 parts of a soil will absorb about $1\frac{1}{2}$ parts of carbonate of lime; or, comparing this with the previous illustration, you will perceive that an acre of soil 10 inches in depth would arrest 15 tons of carbonate of lime. And we may form a further idea of this power in altering the chemical composition of water, by calculating the effect which the filtration through a soil would have upon Thames water. Supposing this water to contain 14 grains of carbonate of lime in the gallon, it would be found, from the above data, that an acre of soil 10 inches deep would remove the carbonate of lime of about 17,000,000 gallons; or, if the water have to pass through five feet of soil before reaching the drains, 100,000,000 gallons would be purified by the filtration.

Supposing you were to apply the results of your experience to the practice of collecting and storing water, and supposing it were desired to obtain water which had fallen on the surface in the greatest purity, would your experience enable you to express a confident presumption in favour of filtration by percolation through the soil as a means of obtaining pure water rather than collecting it off the surface?—Certainly. My experiments would lead me to believe that water which had percolated the surface-soil to any depth, from 2 to 6 or 8 feet, would, as a general rule, be purer than water either flowing over the surface or taken from greater depths. I have found that different soils possess the power of removing salts from water to a different extent. Water which has passed through surface-soil is deprived of its salts to a greater extent than water passing through a soil which has never been cultivated; and there are some kinds of soil (those least fitted for cultivation) which would give up to water any salts they might contain rather than serve to purify it. It is for this reason that I believe that water percolating cultivated soils would, on the whole, be freer from salts than that collected on the surface or taken from great depths.

Would not water, after having passed through one description of soil and lost its salts, be likely to obtain more mineral matter in percolating other varieties of soil?—Yes; I have before observed that water will possess the character of the rock through which it last flows and from which it issues, unless in the case of sandstone districts, which probably neither give to or take anything from water. I think, however, that from what we now know of the action of clay upon water, we may safely conclude that many other strata of the earth besides the deposits of clay will possess the power of greatly modifying the character of any particular water.

Does your experience enable you to prefer any kind of earth, looking to the agricultural objects, namely, the retention of a certain quantity of the salts required, and to the sanitary object of

having the water free from such salts as would be injurious or useless? Can you, in fact, point to any one description of soil that, for domestic purposes, would form a better filter than others, supposing the filtration to be by shallow drains near the surface? —I attribute the property in question solely to the clay; and I believe that the circumstance of surface-soils (such as those mentioned before as containing only 30 or 40 per cent. of clay) possessing this power in greater intensity—weight for weight—than pure natural clay, is due to the production of a greater amount of the active substance in those clays which, by cultivation, are exposed to atmospheric and other agencies; but there is plainly a distinction to be drawn between the circumstances most favourable for the mere *collection* of water comparatively pure, like rain-water, and those which would conduce to the purification of a water impregnated with salts, such as the water of all rivers.

For the collection of the rain-fall of a given district, what soil would you prefer?—I should say decidedly a sand. Rain-water, when collected at a distance from towns, is fit for every purpose, and contains, I imagine, little which in a sanitary or domestic point of view it would be important to separate. All that is required from the collecting surface in this case is, that it shall perform its office without imparting to the water anything to render it impure. Sands which have been washed by rain for ages are most likely to fulfil this condition, and would possess the further advantage of allowing the ready escape and collection of the water.

Keeping in view the practical improvements already referred to in the supplies of water to many northern towns, by collecting the surface water directly, instead of adopting the river waters, we commenced by obtaining specimens of surface waters, which appeared to afford favourable promise, chiefly those from clays and from loams, at various points, near the Thames, from Reading to the district in Kent which discharges into the Medway. We had in view the sandy soils, though we thought it desirable to direct examination in the first instance to those nearest the metropolis and the river, which happen to be clays. Amongst a group of specimens of waters, presented by the water Companies to Professor Brande for analysis, comprehending specimens of all their waters, was one from the Ruislip reservoir, the water of which is used for feeding the Grand Junction Canal. This reservoir is filled from the surface drainage water of a tract of clay land; and the analysis gives only eight degrees of hardness, or just

one-half the impurity from lime of all the rest of the Companies' specimens put together.

The specimens of surface water collected within our own immediate direction gave an average proportion of impurity from lime, of less than half the hardness either of Thames water, or of any other water derived from the chalk formations. It is unnecessary to go over all the specimens which were collected, as indications only, for our town guidance, and we shall confine ourselves to the chief sources which appeared to be available for the relief of the metropolis.

The surface specimens of the water from the weald of Kent were examined. An extent of gathering ground in this district, consisting of waste and inferior land, sufficient for the supply of the whole of the metropolis with water of a high degree of purity, is reported to us by our Inspector, Mr. Cresy. Some of the tract consists of sand, yielding water of not more than six and a half degrees of hardness, and the whole is drained into the River Medway. Specimens of the Medway itself, supplied to us from near Tunbridge, give only four and three quarter degrees of hardness, or one-third the average hardness of Thames water. If a river source were indispensable as the main source for the supply of the metropolis, this would be one which from its superior softness and purity, we should deem worthy of special attention, and because we believe, moreover, that it might be brought to the metropolis at considerably less expense than the amount estimated as necessary for bringing the water from any of the distant points up the Thames.

The searches made south-west of the metropolis appear, however, from the nature of the strata, to be attended with the greatest promise of success. Mr. Donaldson, the agricultural surveyor, engaged under the Metropolitan Sanitary Commission to report on the drainage of suburban marsh lands, having been requested to examine the means of providing combined works of drainage and water supply for some of the suburbs of this metropolis, was required under the Metropolitan Sewers' Commission to inquire as to means for the sanitary improvement of Richmond and

Sydenham. Richmond Park itself appeared to form an eligible gathering-ground, not merely of surface, but of shallow spring water. As the evidence in relation to this one plot of land is illustrative of the principle of improved supplies, we submit it at some length.

You have also been led by your avocations to make examinations as to the state of the surface soil and sub-soil of large tracts near the metropolis, and the qualities of the waters with which they are charged?—Yes, I have done so all round the metropolis.

Within what distance?—Within 12 miles on the north, and from 25 to 30 miles on the south-east, south, and west.

To take one instance closely adjacent to the river Thames, that of Richmond; had you any instances there of drainage, or what may be more properly termed artificial spring water?—Yes; a large part of Richmond Park has been very efficiently drained, under the direction of Her Majesty's Commissioners of Woods and Forests; and from those works there arises a constant and copious supply of artificial spring water.

What is the nature of the soil?—It is a sandy or gravelly loam, incumbent in a clay subsoil.

What did you find to be the quality of the water derived from this surface?—It was perfectly clear; soft to the feeling, well aerated, and pleasant to drink.

Was it so clear as not to need filtration?—It was so clear, that I would not think of filtering it for drinking. It was more brisk than filtered water usually is.

What was the analysis?—There were several specimens from the tract of land drained. There was a large portion of water which had only three degrees of hardness. The average of six specimens was four degrees and one-third.

Would that have been the average of the bulk of all the water taken from the park?—I think the average of the bulk would have been about five degrees.

What at that point are you aware is the average degree of hardness of the Thames water which runs beneath Richmond?—I believe it is about 13 degrees.

That is to say, about three times as hard as the artificial spring water from the land close by?—Nearly so.

Had you any opportunity of comparing the surface water from the undrained portions with the shallow spring water derived from the portions drained?—Yes, several opportunities.

What were the characteristic differences?—The surface water generally holds in suspension earthy and other matters, taken up in passing over the surface.

Did you get these surface waters analysed?—No, I did not think it necessary for the purpose in hand. I am, from long

observation, aware that water passing through a bed of vegetation does leave behind, not only the matter in mechanical suspension, but much of the matter in chemical solution. This is a point which has hitherto not received the attention which its importance deserves. I am quite sure that a bed of vegetatiou will detain for its food saline and other matter in solution, which no sand or other artificial filter will separate from the water. I have seen water, containing a considerable quantity of sewage from a farm-yard, which has passed upon well-drained pasture land, and the water which has drained through it has come out perfectly clear from the manure in solution.

Was it so clear that you would have drank it?—I have freely drank it. It had all the appearance of, and tasted as perfectly pure as spring water.

It is to be presumed, however, that there might be an extent of manuring or shallowness of the filter-bed of earth which would not detain the matter in solution?—No doubt of it. Wherever the drainage is shallow, and the quantity of manure excessive, no doubt some of it would be left in the water. In the case I referred to the drainage was from 3 feet to 4 feet in depth.

You were only understood as stating that filtration through a bed of earth would detain matter in solution which a common sand-filter or any other mechanical filter would not detain?—Clearly so; that is, when the surface of the land is covered with vegetation.

It accords with your observation, then, that shallow or artificial drainage water is of a superior quality, and must generally be so, to ordinary surface water?—Decidedly so.

Does it also accord with your observation that it is superior to the common river water?—Greatly superior in purity to the common river water.

What is the extent of gathering ground for shallow spring water which the whole of Richmond Park might afford when all drained?—The whole of the park is about 2,337 acres, of which nearly 2,000 acres might be made available as gathering ground.

What quantity of water might be derived from that 2,000 acres?—About 400 millions of gallons per annum.

What is the average rain-fall there?—I estimate the rain-fall at 25 inches, of which I think 10 inches may safely be calculated upon as the quantity which could be collected and stored.

Are there any local peculiarities to account for a deviation, in this instance, from the ordinary calculation of the collection of surface-water from rain fall, namely one-third the amount of the annual rain-fall?—There are; the nature of the soil on the surface is such as to absorb water as it falls; also the nature of the subsoil which is such that very little will percolate so as to be lost.

Have you observed an advantage in this shallow spring water

in its freedom from animalculæ as compared with other water?—I never met with animalculæ in spring water as it came from the spring or drain.

Take the case of Richmond, what number of houses would such a gathering ground as Richmond Park supply at the rate of 50 gallons per house per diem?

Have you estimated the extra value to each house if it were supplied with water of this quality, viz., one-third the degree of hardness of Thames-water—would it not be an immense saving in soap?—No doubt of it; but more specific information on this subject, derived from actual experience, is desirable.

Would you think it necessary to use any filtering remedies for such water?—I think it would be unnecessary if the reservoir were suitably made. The natural filtration through which it has passed is in my view superior to any artificial mode.

Were you not called in to report on the sanitary condition of Sydenham?—I was.

Did you find any surface-water there?—Not much worth notice. The land is mostly clay, and the surface-water was hard and rather brackish, so was the water from the wells, and charged with a clayed colour. It would not answer for household purposes; a little beyond Sydenham, some half mile from the town I found a supply of only two degrees of hardness. I did not gauge the quantity, but think it would be sufficient for all Sydenham.

What is your estimate of what the water supply could be furnished to Richmond for, per house, from the supply in the park?—Seventeen shillings and six pence per house per annum would repay the whole outlay with interest in 22 years, and cover the cost of working and superintendence.

Suppose the population had the choice of the Thames river water or this shallow spring water, what would it be worth while for the inhabitants to pay per acre, if they could be supplied with 100 gallons per diem as compared with the supply of the river?—As affecting health the difference between pure spring water and the Thames water is above all price; as a matter of economy in washing and for other domestic uses, it would be worth an annual payment of three guineas per acre, assuming the water not to exceed five degrees in hardness.

How many families at your estimate of the gathering-grounds can be supplied per acre?—One inch deep of rain-fall on an acre will supply 10 cubic feet per day for a year, which I assume as a minimum quantity per house per diem. So the depth in inches of rain-fall obtainable, indicates the number of families it will supply during one year. The average rain-fall being 21 inches, one-third of that would supply seven houses. Assuming the number of houses in the metropolis at 300,000, and assuming the rain fall per annum at 24 inches, one-third of that, = 8 inches, gives eight families per acre; at this rate it would take 37,500 acres, or 58 square miles of gathering-ground. The irregularity of a rain

supply necessitates large reservoirs, equal to three or four months supply. The cost of draining 37,500 acres, at an average of 6*l.* per acre, will be 225,000*l.*, which would amount to 12*s.* per house. That is to say for the original outlay, but involving an expense of, say 6*d.* per house per annum rental, for this method of filtration.

What is the total amount of acreage it would form?—About 10,000 acres.

On the accustomed estimated supply of 100 gallons per diem for each house (which is an estimate on an average of houses including inns, breweries, &c.), the quantity of gathering ground requisite for a town of 2,000 houses, supposing the fall of rain to be 30 inches, will be under 300 acres, or one square mile will suffice as gathering-ground for upwards of 22,000 of population; an acre for the annual supply of about 35 inhabitants.

It is reported to us, that the quantity lost by evaporation, vegetation, springs, &c., is almost constant, and will range from 15 to 20 inches annual depth. From a rain-fall of 60 inches, as in the higher parts of Yorkshire, Westmoreland, Derbyshire, and Cheshire, at least 40 inches might be impounded and rendered available. In Bradford, Leeds, Sheffield, and towns similarly situated, where the rain-fall does not exceed 35 inches, 15 inches might be obtained. In Norfolk, Cambridge, Suffolk, and counties similarly situated, with an annual rain-fall of only 24 or 25 inches, not more than 9 inches could be obtained.

As one alternative for obtaining supplies of greater purity than the Thames, or common river waters, were it necessary to have recourse to such an expedient, it is stated to us that crown lands, of which there are about 10,000 acres within 10 miles of the metropolis, might at a comparatively small expense to the public be secured, from occupation of the land, and pollutions from unskilful or excessive top-dressing with manure; while these lands and woods would have the benefits derivable from improved drainage.* But sources of higher purity than these have been developed.

* It has been determined by observation, that if the annual increase of trees on undrained land were 3 per cent., the increase on drained land would be 6 per cent.; and on land both drained and irrigated, no less than 12 per cent., or four times the amount of growth on undrained land.

Extending the enquiry to the sandy districts at Claremont, we found surface-waters of three degrees of hardness; and at Bagshot, water of still greater purity, being less than two degrees of hardness. Mr. Richard Phillips says, he never met with water of greater natural purity. We had given directions for a close examination of the extensive district, commencing with Bagshot and Woking sands, and extending to Hampshire, when Professor Way called our attention to a specimen of water, which he had found at the other extremity of the district, at the town of Farnham, which was supplied by the drainage of a small portion of the tract. The specimens of water so derived, which he analysed, were only of half a degree of hardness, and were in other respects of extraordinary purity. The town of Farnham is, it appears, situated on the borders of the chalk formation, and the water there being very hard, it had been the practice for washer-women to send carts about half a mile, to some springs rising from the common, consisting of a large tract of sandy land, which commences near Farnham Castle. This experience of the value of the soft-water suggested its adoption by a small joint stock Company, for the supply of the town. At the instance of Mr. Paine of Farnham, an eminent agriculturist, agricultural drains were put into rather less than two acres of the common land; these were led into a small reservoir or rather well, as it is not more than four feet diameter and ten feet deep, and from thence, the water is delivered to the town, by a constant supply at a sufficiently high pressure for its delivery to the top of every house in the town.

The surface of the common is generally heath and peat, and at some periods, during heavy floods, the water is apt to acquire colour from an infusion of peat. This is a characteristic of the surface waters from the waste lands selected for the supply of Manchester and some other towns; but the infusion subsides, and the colour in these waters is removed by motion and aëration. This infusion is a drawback from perfect purity, but probably the least objectionable one in a sanitary point of view, as the anti-septic qualities of peat are well known. The experience of filtration, or

derivation of the water by thorough drainage at Farnham is highly satisfactory on this point. The thorough drainage divests the water of all peaty colour, and it is delivered clear and limpid at all periods of the year.*

Mr. Paine gave strong testimony, that from his own knowledge of the nature of the surface there was no reason why the same quality of water should not be obtained from the whole of a tract of waste land there, ten miles long and five broad, essentially the same as that from which the Farnham supply was derived. Over a considerable proportion of the land the peat is so thin, as to admit of the surface being laid bare at a moderate expense.

The popular experience of this water, was consistent with the like experience in other towns; it was in high repute for washing, for making tea, and for brewing. In Farnham itself, there had been no attention bestowed on the distributary apparatus, so as to regulate temperature, and preserve the purer aëration so essential to the usefulness of drinking water.

We obtained the aid of Mr. R. Austen, a distinguished Fellow of the Geological Society, who had paid particular attention to the sand formations in that district, to re-examine this tract of land with Mr. Ramsay, the Local Director of the Geological Survey for Great Britain. We deemed the observation of Mr. Ramsay of peculiar importance, as he had surveyed the district in which the celebrated Bala Lake is situated, and had paid particular attention to the surface waters derivable from the slate and other formations.

Their examination was directed to the sandy tracts in that direction, the whole of which with but small portions excepted, are either commons or wastes.

Stevenson in his Report to the Board of Agriculture on a survey of Surrey, thus describes the tracts :—

> The greatest part of the heaths of Surrey lies in the west and south-west districts of the county, extending from Haslemere to Farnham, and from Farnham by Bagshot to Egham. In this wide extent there are very few spots of cultivated ground.

* As to the quality of this water for culinary purposes, *see* evidence of M. Soyer.

Speaking of heaths of which these proposed gathering grounds form a part, he says:—

The whole of these extensive heaths may be fairly considered in their present condition as of very insignificant value. A very few poor-looking cattle and sheep are seen scattered over some of them picking up a scanty support with much difficulty and labour. Turf is, perhaps, the produce they afford in the greatest abundance and of the most value.

A great part of Hurtwood, especially in the higher parts of it between Shire and Ewhurst, consists of a worthless white sand covered with short stunted heath; perhaps the wildest and bleakest part of the county lies between the two places just mentioned.

This soil, though of an inferior quality, and appearing along with some strong land, merely like spots, amidst the wild and desolate heaths, is to be found the whole way from the road between Kingston and Ripley to the western limits of the county on the borders of Berkshire and Hampshire.

Vancouver, in his survey of Hampshire, says:—

Proceeding farther to the northward, this temperate mixed soil is again lost in a thin sand and gravelly mould, upon deep beds of white, red, and yellow sand and gravel, and a wet hungry loam upon a moist, loose, white and yellow clay, and altogether forming the leading character of that extensive range of heath land which forms the southern borders of Berkshire and a part of Surrey, constituting a part of Bagshot Heath and Frimley Common. On a general view of the soil of this district, the woodlands may be said to consist of a tough sour clay. The heaths and commons interrupted with peat and swampy bottoms afford but indifferent pasturage on substrata of gravel, wet and poor sandy loam.

The improvement of most of these tracts has hitherto been given up in despair, and the growth of fir is recommended as the only agricultural purpose for which they are fitted.

Of the geological character of a considerable portion of the district which we have had under examination, Mr. Robt. Austen, the geologist, says,—

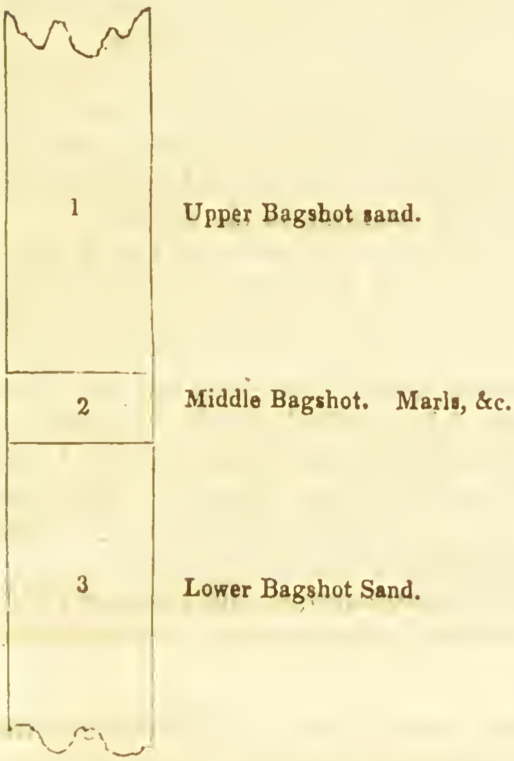
" The Bagshot sands, as a continuous series of beds, " extend from Esher to Strathfieldsaye, east and west, " about 30 miles. Their width is variable; they occur " north of Virginia Water, and their most southerly point " is on the summit of the high ground above Farnham. " If we estimate them to have a mean breadth of 10

"miles, they will cover an area of 300 square miles. "The composition of the beds of this series is remarkably uniform; the upper portion consists of pure "silicious sands; this division attains its greatest thickness about the north and east portion of the mass, as "at Bagshot Heath, Chobham ridges, Romping downs, "Finchampstead ridges, Hartford Bridge flats. These "sands are from 200 to 300 feet in thickness.

"Beneath these sands is a retentive stratum of marl "and clay, varying from 5 to 15 or 20 feet in thickness. The lowest portion consists of white and pale "yellow sands, pure silicious for the most part, the "subordinate argillaceous strata being at the eastern "portion of the mass."

Referring also to this portion of the districts that we have had under consideration, Mr. Ramsay states—

Its geological subdivisions are —



Their mineral structure is as follows :—1st. Upper Bagshot sand; generally a fine light brown sand, somewhat of the colour of pale brown sugar. It appears (as far as can be determined without absolute analyses) to be nearly pure silicious sand, slightly coloured by an oxide of iron.

2d. The Middle Bagshot beds, from 20 to 30 feet thick, generally composed of,—

1*	A green sandy bed (probably coloured by silicate of iron composed of the waste of the green sand of the chalk formations.)
2*	White and pale yellow foliated marls

3d. Lower Bagshot sand; mostly silicious sand of somewhat similar texture to the Upper Bagshots, and darker in colour.

The Middle Bagshots (2) form an irregular and generally narrow band, resting on, and contained within a wide area composed of the lower sands. The Upper Bagshot sand for the most part occupies the higher grounds within this land, such as Romping Downs, Chobham Ridges, &c.

For these, and other physical reasons, (such as its waste character, &c.) it would probably be for the most part desirable to employ the area contained within the circumference of the Middle Bagshot marls for the collection of water from the surface.

The whole series is often obscured by a superficial covering of loose sand and gravel, varying in thickness from a few inches to 20 or 30 feet, and this in the higher waste grounds is generally overgrown by a thin covering of heath. As far as I am aware no deep extensive mosses exist, or are common in the district.

Owing to the incoherent texture of the Upper and Lower Bagshot sands, they are easily percolated by water, so that a large portion of the rain that falls on the district must necessarily in the first instance be absorbed. This circumstance is rendered apparent by the fact that the smaller valleys branching out on either side of Chobham Ridges were, when visited by me, destitute of brooks. The water so absorbed is, however, checked in its downward course by the Bagshot marls (2), and when the disposition of the strata is favourable, it is thrown out to the surface at the junction of these marls with the upper sands (1), forming a series of springs round the retentive marly outcrop, and frequently collecting in pools of considerable area, when partially intermingled with the surface drainage.

The portion of this district to which our attention has been more immediately directed, comprises an area of less than 100 square miles lying east and west of a line from Bagshot to Farnham. The remaining district which we have had under consideration, although of the same bleak and barren character, is of different geolo-

gical construction, consisting of the upper and lower green sands and gault of the Green Sand Formation, and constitutes the uncultivated sand districts draining into the east and west tributaries of the river Wey, situated south of the chalk ridge in the midst of which the town of Guildford stands.

Dr. Lyon Playfair, thus describes the chemical properties of the sands:—

> Much of the sand is altogether silicious, and contains no ingredients likely to have any unfavourable influence on the water. Some specimens of sand, however, contain a considerable quantity of protoxide of iron, which is liable to be dissolved by the carbonic acid of the rain water. I have, however, been informed by Dr. Smith, who has had more opportunity than myself carefully to examine the district, that this sand is of very limited extent, and that he has found few waters containing an appreciable amount of iron.

Dr. Playfair, accompanied our engineering inspectors in their survey, and took specimens on the spot. About 30 specimens were examined by him at different times. Dr. Angus Smith inspected the district for about a fortnight, and examined about 80 specimens of water taken from different parts at different times. Several analyses were also made by Professor Way.

It is to be observed, in respect to the results of these examinations received collectively, that they are in accordance with the principle previously enunciated, that the nearer the collection to the actual rainfall the greater the purity of the water.

The specimens collected at the surface immediately after the rainfall are of the highest degree of purity, being in large quantities not exceeding one degree of hardness. That portion of the rain-water, also, which filters through an upper stratum of sand in parts of the district, and appears again at lower levels after passing through a few feet of the upper stratum, is of an equal degree of purity.

Those specimens taken from the streams and ponds when the water has run some distance, are of more than two degrees of hardness; those taken lower down in the streams rise to about four and five degrees of hardness, before mixing with streams derived from the chalk or clay formations, which increase to as much as eight degrees of hardness.

The chief practical result deducible from these observations is, that by arrangements for collecting the water before it has traversed any great extent of surface, a quantity sufficient as it appears for the domestic supply of the whole metropolis will be obtainable at a very high degree of purity, probably equal to the present supply at Farnham. The general results of the chemical investigations may be described in the following evidence of Dr. Angus Smith:—

You have examined the waters of most of the gathering grounds for the improved supplies of the Lancashire towns, have you not?—Yes; I was engaged for the examination of the Manchester new supplies, derived from gathering grounds, on the hills between Lancashire and Yorkshire; and also the proposed gathering grounds from hills to the north of Derbyshire, and some from Cheshire. I examined the gathering grounds for the supply of Bolton, and part of the gathering ground appropriated for the new supply of Liverpool, and also those for the supply of Burnley and other towns in Lancashire.

In those instances, the proposed gathering grounds were wastes and moors, were they not?—Always so.

Did you examine the supply proposed by Mr. Rawlinson to be brought in for Liverpool from the Bala Lake in North Wales?—Yes, I did.

In all these cases you went to the grounds yourself, and collected for yourself the specimens for analysis?—Yes, I did. I may observe that besides the grounds mentioned, I have examined the water from grounds in other districts, simply to determine some questions for myself, as to the effect of peat upon waters.

You completed practical analyses in the several cases for advising on improved supplies for the use of the population of the several towns?—Yes, I did.

We understand you to concur generally in the conclusions from evidence we have received, and which you have seen as to the superiority of soft water over hard for drinking, for culinary purposes, for washing, and for manufactures?—Yes, I do. The most earnest attention has been directed in Lancashire, however, to the importance of soft water for manufactures. The number of schemes which have been proposed for removing lime from boilers, or for removing it from the water, show the importance that manufacturers have attached to the subject.

You have now visited a number of waste lands, heaths, and moors in Surrey and Hampshire, which have been pointed out to your consideration as eligible gathering grounds for improved supplies of water for the metropolis, and have examined specimens of water from them?—Yes, I have been over these grounds nearly a fortnight, and I have examined about 80 specimens of the water. For two days I was accompanied by Professor Way.

Before entering into the particulars of your examination, will you state the character of the waters obtained, as compared with the water derived from other gathering grounds which you have examined; and, first as to the Bala Lake; have you the analysis of that water?—Yes; it is the following:—From the Dee, at Llangollen—

Hardness	2·5
Carbonate of lime . . .	2·1
Alkaline salts	·532
Salts left by the decomposition of the organic matter	·168
Organic matter	2·8
Entirely peaty matter . . .	

I had too little water for further particulars.

You have examined the water as supplied to the town of Farnham?—Yes I have.

Will not the Farnham water represent a fair specimen of the water derivable from a large extent of the proposed gathering grounds?—Yes, allowing the average of the Farnham water to be about two and a-half degrees, it will represent the quality of the water derivable from the whole of the eastern part, that is from 20 to 30 square miles of gathering ground as far as I have seen, nearly all waste.

Will you give in the analysis which you have made of this water?—The specimen of Farnham water which I received was unfortunately taken from a place where impure matter from a garden was allowed to enter. I shall therefore give the analysis made by Professor Way—

	Grains in a Gallon.
Silica	·55
Lime (as silicate) . .	·375
Sulphate of lime. . .	·280
Sulphate of magnesia . .	·557
Chloride of magnesium .	·552
Chloride of sodium . .	1·440
Chloride of potassium . .	·354
Organic matter and water of combination . . .	1·245
	5·323

so far I can corroborate this, that I found a spring on the same hill containing 2·76 grains of inorganic matter in a gallon, and ·75 of organic.

From the gaugings taken at the end of six weeks' rain-fall, it is reported to us that the extent of supply derivable from these wastes which are distinguishable from the rest would be about 28 millions per diem, or equal to a daily supply of 100 gal-

lons per house in the metropolis; will you state the general character of this water as compared with that of the Bala Lake?—I cannot speak to the quantities; but in respect to quality, the Farnham water is equal to the mass of any Lancashire or Cheshire water derived from the gathering grounds which I have examined. In softness it is equal, in some places superior to the Bala Lake water, from the proposed collecting point above Llangollen; it is also less coloured with peat than the water of that lake. There are portions of water derived from what is called the rough rock in Lancashire nearly as perfect in every respect as distilled water; but the gross amount of the Farnham water would be equal to any other gross amount of soft-water supply for a time which I have examined, taken indiscriminately.

We are now speaking of the water as at present derived; but may it not be even further improved by care in its derivation or collection?—Yes, materially.

In what way?—By under drainage chiefly.

Will you describe the advantages you expect from under or shallow drainage?—My view is that most rain-waters will be improved by passing through an appropriate filter. My belief is that all water coming from rocks or sand is more brilliant than simple rain-water. All rain-water is apt to bring down with it vegetable or animal matter floating in the atmosphere.

Where have you made collections of rain-water?—In Manchester and the neighbourhood of Manchester.

Then you probably give us an impression simply, and not the results of experience, as to rain-water falling in purely rural districts?—Yes, that is so; but still I should prefer the water which had passed through a filter, as purifying itself from the matter caught upon the surface, for some foreign matters are caught upon the surface of all gathering grounds which have yet been found, or are likely to be found, for town supplies.

You have examined microscopically the waters taken from Farnham, have you not?—Yes; and I found very little animalcular life—remarkably little; indeed, I only found it in one instance, and that from what might be called a stagnant pool, and the animalculæ were not *always* such as come from vegetables. I shall describe them in my report.

Are you aware whether in any of the towns now supplied, or to be supplied, with soft water from gathering grounds, as at Bolton or Manchester, under drainage has yet been thought of?—No, none of them.

Even if the surface water were taken, as for the northern towns, from the surface of the district, crudely as at present, and without any further improvement, would not the general supply from the entire district you have examined be superior to most river-waters, not to speak of the Thames?—Yes, certainly. It would have the greatest superiority in respect to softness; it would have less mineral, and would be nearly pure from animal matter; and

it would have less vegetable matter. The only matter in it is peat, and that is not visible to the eye. I except some portions of the district which might be separated or improved.

The whole district is supposed to be covered with sand; if so, what portion is covered with the same description of sand?—Speaking roughly, I saw 20 miles of land, and 30 miles of shingle and sand.

What are the chief causes of the variations in the quality of water which you find in this district?—Variations arising from peat chiefly.

Is not the peat very thinly spread over the whole district?—It is not thick anywhere; but the variations in the quality of the water are caused by the state and inclination of the surface, which occasions the rain to wash the peat surface alone before it is discharged into the brooks.

We understand, then, that by the shallow drainage which you contemplate, you have in view the instance of the derivation of the water for the supply of the town of Farnham, by which the water falling on the surface of peat, passes through the peat, and thence through the sand into the tile-drain, cleared of the peaty infusion?—Yes, that describes the process.

What is the depth of the peat on the gathering grounds for Manchester?—Some of it about six feet deep; a great part of it about four feet deep.

What was the depth of the peat on the gathering grounds for the new supply of water for Liverpool?—That which I saw was from two to three feet deep.

Mr. Donaldson, the agricultural surveyor, reports to the Board, that the surface peats on the Surrey wastes is so thin, much of it some six or eight inches thick, that it might be taken off at a cheap rate?—Yes; but from the instances which I observed, it would suffice to take off two or three inches of peat from the surface.

You do not, then, think that the infusion of peat, even if the water were taken as it is, would be highly objectionable?—No, it is not thought so; peat itself is highly antiseptic; it is not considered favourable to the production of animalcules; it is not directly convertible into animal life like the organic matter in the Thames, and most river water. The only objections I know to it are the taste and the colour, which are disagreeable when the infusion is considerable.

Besides the instance of shallow drainage in this particular district, have you observed shallow-drainage waters in other districts?—Yes, in a few instances. I may mention one at Rochdale, where the surrounding waters went as high as 13 degrees of hardness; but the shallow-drainage water obtained from a ploughed field was about four degrees and a-half. The comparative purity of the drainage-water in other points was similar.

Will you state your own view of the powers of the surface

stratum of land for depuration?—I passed a strong solution of peat through a filter of sand, and found it quite purified. I passed then an ammoniacal solution through the filter, such as is found in warm weather on the tops of hills on peat, and found it quite clear. Then an acid solution was passed through, which also was quite purified. Afterwards, I passed the same solution of peat as at first through various materials; oxide of iron, manganese, lime, and iron filings; all of which substances purified the peat. I then passed strong solutions of woody matter in mineral acids; these also became pure; sulphuric acid and muriatic acid, for example. The matter was left chiefly on the surface of the filter. I observed also that all the peaty districts have a black stratum a few inches deep, below which there seems to be no organic matter, or very little. A similar stratum, not coloured, may be observed on all soils, but rather deeper. Water taken above the point of filtration, that is, not having passed below this stratum, contains much organic matter; but below this line it is true drainage water, and is purified like water from a shallow spring. Leaving the cause for examination elsewhere, these facts lead to the conclusion that the power of filtration to remove colouring organic matter in solution is really enormous; but it must have time, as the action is not a mere straining through a sieve; the artificial filter is for this reason generally too small for the full effect obtained by the natural mode of filtration, where time is given for a complete act of purification.

Will you describe the general condition of the other remaining districts?—The Frensham district is entirely a loose sand, with very little peat, the water harder than the northern and eastern portions, but I think it might be had softer if the district were drained faster, an experiment which I made showing me that the hardness was, in a great measure, if not entirely, caused on the surface. The Frensham pond may be called a specimen of the inferior class of water of the district. It is 5·45 degrees of hardness, and contains 6·9 grains of dissolved matter; sulphate of lime, 2·29 grains; carbonate of lime, 2·343 grains; chloride of calcium, ·995 grains; chloride of sodium, ·66 grains; and chloride of kalium, ·118 grains. It contains also a little, very little, magnesia and carbonate of soda,—with silica, which, I believe, I have not yet estimated. This is a third of the hardness of the Thames, taken at the best points, and a third of the solid contents of the water at present delivered. The districts of Hurtwood and Leithhill are covered with gorse, heath, and wood, and the water will, I believe, be found good, under any mode of collection, that is whether drained or not. I have founded my opinion of the water independently of the Bagshot eastern district. The water from which, as it at present flows is too much coloured by peat, and so much so as to be disagreeable to the taste. I saw abundant reason to think, however, that by careful filtering in its natural position, it would be completely purified, and would then make a valuable gathering

ground. In company with Professor Way, I saw instances of purification in this manner. I have, therefore, only to speak of it capabilities as a gathering ground, but not of its present supply of water.

Do you see your way of obtaining any supplies of equal purity for the metropolis?—I know of no other silicious district near London, and I take it for granted that there is none producing soft water or geologists would have pointed it out. Any natural soft supply, therefore, seems entirely beyond all expectation and the only mode of obtaining it would seem to be by artificial purifying. As the process of purification could not by any means yet adopted bring it to a point softer than the district proposed, I see no inducement to try any hard-water supply, and to be at the trouble of artificially softening it; whilst, I may add, that the artificially softened water does not equal the natural supply, and may be otherwise objected to.

Dr. Playfair gives a concurrent opinion upon these new sources of supply, and as to the means of still further improving them —

You have examined the waters of most of the gathering grounds for the improved supplies of the Lancashire towns, have you not? —Yes, I have.

In those instances, the proposed gathering grounds were wastes and moors, were they not?—They were; in some cases the soil being of a peaty character.

In all these cases you went to the grounds yourself, and collected for yourself the specimens for analysis?—Yes.

You completed practical analyses in the several cases for advising on improved supplies for the use of the population of the several towns?—I examined carefully the waters, both for their organic and inorganic constituents; and also made it a special object of inquiry to ascertain the effect of peaty matters in solution, with a view to see how soon it became discoloured by exposure to air and light.

You have visited a number of waste lands, heaths, and moors in Surrey and Hampshire, which have been pointed out to your consideration as eligible gathering grounds for improved supplies of water for the metropolis, and have examined specimens of water from them?—I visited them in the company of the Secretary and one of the engineering inspectors of this Board; and then collected waters, and have since examined them.

Will you state the character of the specimens of water derived from these sources, as compared with the water derived from other gathering grounds which you have examined?—The surface waters which I procured were in general colourless, of good taste, and were soft in their reactions to soap and for the purpose of detergence generally. In various instances they were quite as soft as the waters taken from the gathering grounds from which

Manchester and Liverpool will be respectively supplied. In other cases they were of a moderate degree of hardness; but the general average mixture will produce a water of very superior quality and of softness.

From the nature of the surface, will you describe the qualities of water which in your opinion may be expected from it, and how far the qualities coincide with the analyses of specimens which you have made?—As a general result, founding my opinion not on my own examinations merely, which have amounted to thirty-six, but from a consideration of Dr. Angus Smith's analyses, which amount to about eighty, I would say that you might expect a water of about 4 or five degrees of hardness, the soft waters being mixed with the harder specimens. The amount of organic matter in most instances appears to be inconsiderable. When it exists it seems to be of peaty origin. This is the least noxious organic ingredient in water; because, by the action of oxygen, it speedily becomes insoluble. When coloured peat water comes in contact with other water not containing peat, as it would do by being mixed in a reservoir, the peaty impurity soon is rendered insoluble by the air dissolved in the latter. Sheffield is supplied with water from a peaty district, but much of the colour disappears by the natural process of aeration; although the water is still delivered to the inhabitants in a coloured state. This colour the inhabitants do not seem to object to, although it is obviously not to be desired.

This conclusion appears to apply to the whole mass of waters derived from upwards of 150 square miles of gathering ground. Will you state your view in relation to the waters of which you have made examination from between 70 and 80 square miles of these grounds, the numerical average of which appears to be 2½ degrees of hardness, and which in volume is stated to promise a supply of upwards of 28,000,000 gallons per diem. Supposing this quantity to be available, how would you class this water, as a supply for an urban population?—A water of $2\frac{4}{10}$ degrees of hardness is a first-class water, being very much softer than that supplied to most towns in this kingdom. In fact there are only a few exceptions in which soft water is used for public supply.

The testimony of Professor Way in relation to the value of the waters, as now derived from these grounds and the powers of improvement, it will be perceived is generally in accordance with that of Dr. Lyon Playfair and Dr. Angus Smith.

Mons. Soyer gives the following evidence as to the value of the Farnham water, for culinary purposes:—

You were requested to try as completely as you could some soft water from Farnham, and ascertain its value for culinary purposes, have you done so?—Yes, I have compared it on trial with between 40 and 50 specimens of different waters; some I had

from Ireland, some from Scotland, and I found it the best of the whole, and very nearly of the quality of distilled water. In cooking some vegetables, however, I found the artesian well water somewhat better than the Farnham water.

The water of the artesian well is alkaline, and that is a quality peculiarly favourable to solubility?—Yes.

As a soft water, do you find that the Farnham water has the general power which you ascribe to the softest waters—generally as compared with the river Thames water?—Yes; for, as compared with the Thames water, its power of extraction would then be as about six to four. But the flavour of the tea produced by softer water would be greatly superior.

Was the proportionate rate of boiling the same as that which you ascribe to other soft waters?—Yes, very decidedly; it boils, in the quantities I used, much quicker than the hard water.

We have given the medical evidence as to the effects upon the public health from the change simply from a hard to a soft water supply; but we were desirous of ascertaining the popular appreciation of changes such as we propose in the qualities of the supply for the metropolis; and we directed particular inquiries to be made for the purpose.

The improvement in the quality of the supplies by the substitution of soft for hard water, and in the distribution, by substituting the constant for the intermittent system of supply, have in most instances we have met with been accompanied by defects of old and badly constructed works, the use of which was continued after the change had been effected, and by all the inconveniences arising from the separation of the works of water supply from the works necessary for its household distribution, and from those required for the removal of the waste water. Thus in Paisley, Glasgow, and other places where the constant supply has been introduced, the drainage works being separate, and there being little or no provision for proper house drains, a large proportion of the population are still supplied by stand-pipes, which entails so much labour in carrying water up stairs as to restrict its proper use, whilst it entails the pollutions and loss of temperature from the retention of the water in close and heated rooms. In addition to defects in the mode of delivery, the process of previous filtration is not so perfect as it might be, and in some instances complaints have been

made as to the impure state of the water, from the Companies having declined to filter it, in order to save expense to themselves. With all these defects, however, as soon as the original superior qualities of the softer waters become known they have obtained a decided popular preference, and it has been stated in evidence that when the sense of taste gets accustomed to the impression of soft water, the impurities contained in the hard water (and which to some persons appear an advantage rather than otherwise) become decidedly perceptible to the palate. Mr. Stirrat states:—

Have you been among or known populations who, after having been used to soft water for drinking, have had to come to the use of hard, or the converse?—At Paisley they used to have water from spring wells for drinking, but these springs contained iron, lime, and magnesia, although very pure to look at; and the population never complained of their use for anything but washing, for which they were not good. About 30 years ago water began to be carted along the streets and sold to the people. This water was pumped up from the river and filtered, and was much softer than the springs, and did very well for washing and infusing tea, &c.; but since the introduction of soft surface water by the Company, the wells are not used for any purpose whatever, being totally neglected; and for drinking, the water of the Company is universally preferred, and relished the best of any. I may here mention that the quantity now consumed for domestic use is so great, that had the people used the same quantity at the price charged from the barrels above mentioned, it would have cost upwards of 100,000*l.* annually, and for which they now pay under 3,000*l.* annually.

Do you know that well-water derives its attractiveness from its coolness and freshness?—No doubt it does; averaging in summer from 45 to 55 degrees of heat; but our water from the main pipes is also quite as cool and clear, being under constant pressure in the pipes, and no cisterns in the houses where it would become heated and be thereby unpleasant to drink.

But it has been objected to, and particularly by Mr. Thom, that water-pipes have been laid too near the surface?—Mr. Thom is quite correct in this remark; but at Paisley and the Glasgow New Works, the pipes are laid three feet from the surface, and the water is found to be at all seasons quite cool enough. In London, Manchester, &c., where water is taken into cisterns, in warm weather it uniformly becomes tepid and unpleasant to drink. In Liverpool the water is very hard. I could wash at home without soap as well as at Liverpool with soap. I have stated that we are supplied on the constant-service principle, and the pressure (120 feet) has never been off since 1838, when the

supply began, except when occasionally the joints of a pipe were leaky and required repair, which operation is very easily and quickly done.

One general evil in the storage of water is, that where the water is exposed to the sun, vegetation grows and animal life ensues. It appears best to roof the reservoir where that can be managed, and the question is whether a floating roof cannot be constructed?—We have had under consideration the roofing of the filters and distributing tank, which are liable to the objection you mention, and which can be easily done at a small cost; but as to covering or roofing the storage reservoirs, that is altogether unnecessary, as nothing of the kind annoys us in so deep water.

What is your experience as to the effect of soft water in cooking, tea-making, and washing?—Since we have used soft water, there is no comparison as to the value of soft water. For infusing tea, the flavour is good with a much less quantity; and in cooking, we of course get quit of all those deleterious substances which, in an imperceptible manner, generate diseases; and as to washing and bleaching, any industrious housewife can tell the advantage. I should say, from experience as a bleacher, that if I was compelled to use the London or the Liverpool waters in my trade, that for every 1,000 lbs. of soap I use, I should have to use at least 2,000 lbs., and, after all, the same cleansing effect would not be gained.

Do you find convenience and improvement as a landlord from the more plentiful distribution of water?—I certainly do. The houses are much cleaner, and in better condition in all respects. I have the charge of tenements, my own, and in trust for deceased friends, containing about 250 tenants, and I cannot let a house to any good tenant, even of the lowest labouring class, if water is not laid on in it. The poorest person will not take a house without water-pipes in it, if he can procure one with it; and they uniformly prefer a house with the water inside.

Dr. Sutherland confirms these results by local investigations at Paisley, Glasgow, and other towns in Scotland, where it was found, that the superior advantages of soft water for all domestic and manufacturing purposes were fully appreciated by the people. In these and other instances experience had led them to detect the difference of only two or three degrees in the hardness of water from the saving in soap effected by washing with the softer kinds. In regard to those districts in Lancashire where soft water supplies have been introduced, Dr. Sutherland says,—

So far as my inquiry extended, I found that all parties were

unanimously of opinion that very great economy had been effected by the substitution of soft water for the hard formerly in use. Evidence to this effect was given by engineers, manufacturers, bleachers, and brewers, while similar testimony was offered by persons making use of soft water solely for domestic purposes.

The experience of the town of Stockport is valuable, as affording an example of the use of two kinds of water, one of hardness of 16½°, or about that of the Thames water, and the other of 3½°, or about the amount of hardness of supplies proposed to be collected for the metropolis from gathering grounds. Both are supplied by the Water-works Company, the harder water derived from springs in the new red sandstone being known as the lower level water, and the softer supply as the *higher level water*. The following are notes of evidence obtained from Mr. John Lawton, waterman to the Company :—

"All the consumers like the higher level water better than the lower level water, because the higher level water is the softest." The consumers "want it for tea and for washing; it makes much better tea; it uses less tea; it uses decidedly less soap. It is cheaper for washing, and there is less labour attending it. It is preferred by the brewers, because it brews better ale. The soft water does not corrode boilers. At large tea-parties the soft water is used by preference, because it makes tea cheaper and better."

Being asked, "What is the reason people pay for your water, when they can get a supply from their own wells without paying for it?" He replies—"For the reasons I have already given. These give the universal opinions of the people; so much so, that the Company has determined to supply all the districts with soft water, on account of its being preferred."

John Manchester, a bleacher in Stockport, gives evidence as to the superior ecenomic value of the soft-water supply. He says, "Where we should use 50 lb. of alkali with hard water, we use 45 lb. with soft. Hard water takes more alcali and soap to produce the same colour than soft water does. The saving of soap is still more in proportion."

In reply to the question, "What is your experience with regard to the use of hard and soft water for calico-printing?" he says, "Soft water takes decidedly less drugs to produce the same colours."

Another witness, Mrs. Unsworth, of the Mersey Inn, Stockport, stated that there was an old well in the yard of the house, from which water was drawn by a steam-engine, for household use; but, after having gone to this expense, it was thought better to take the Company's water, on account of its softness. She states that it brews better ale than the well-water, and also makes better tea, and uses less soap in washing; so that it was found cheaper to use the soft water than the well-water, although the former had to be paid for.

The town of Blackburn has a water supply of from 3° to 4° of hardness, which has been extensively introduced into factories and dwelling-houses. I made personal inquiries of a number of people as to their experience of the new supply in comparison with the water formerly in use. I found the testimony unanimous as to the superior advantages of the soft water for all culinary and domestic purposes. It was stated that it made better tea, and that it saved soap and labour in washing. A respectable chemist and druggist said that he eould use no other water for making infusions, as all others were hard, and extracted badly.

The following notes of evidenee will show the superior value of the soft water supply in the local manufactures :—

Henry Smithies—" Is an engineer at Blackburn. Is acquainted with the comparative use of hard and soft water for boiler pur poses; is acquainted with the use of the present town water for boiler purposes. The town water is very superior ; it does not produce scale, which the former hard water did. The hard water crusted the boilers so thick that the crust had to be taken out with a pick-axe; the bottoms of boilers got corroded, and the rivets got eaten off. There is no question as to the superior cheapness of soft water, because the boilers last very much longer, and require fewer repairs. The saving of repairs in a boiler in use in our own works made more than the difference of the water-rent paid for the soft water."

The nature of the source requires a preservation of the rain during periods of its maximum fall, for a regulation of the supply during periods of a minimum fall. The storage room must therefore be very extensive. The primary engineering disadvantages of this district are, that it presents no deep natural hollows, such as are available to many of the northern towns, for the storage of water without extensive excavations. Here the excavations for storage reservoirs must be very large and expensive. Against the modern engineering practice of exposed and open reservoirs, we would rather revert to the custom of the Roman engineers, and recommend covering the service reservoirs and aqueducts to the utmost extent practicable.

The above evidence taken together appears to us to be conclusive in favour of the adoption for the metropolis of the principle of soft water supply by means

of gathering grounds. The income derived from the waste lands and moors under consideration, as available gathering grounds, for the supply of the metropolis, in the exercise of manorial rights, or rights of common, is notoriously small, and a fair and liberal compensation, if it be just towards the public, must apparently be a low one.

The service required for the public is the removal of that surplus water which, at present, encumbers the land, impedes production, lowers the temperature not only of the surface from which the surplus moisture is taken, but of the adjacent districts, and by the damp and chill lessens the vigour of human as well as of vegetable life. Properly conducted land drainage operations pay their own expenses in from one year and a half to three years. (*Vide* Report on Suburban Land Drainage.)

Judging by the derivation of the small water supply for Farnham by under-drainage, it might be found to be worth while to use the same method very extensively for increasing the quantity as well as for improving the quality of the discharge. It is doubtful, however, whether at some parts where the sand is very deep, and the present surface indurated, more would not be lost than gained by breaking through the present surface to underdrain it. That doubt can only be settled by more close examinations and trials of the soil. It is reported to us by Mr. Donaldson, that the peat on the surface of the sand is generally so thin, that it may be very cheaply removed, and may, in great part, pay for the cost of removal. This is an operation which may be cheaper than any subsequent one for removing from the water any infusion from the peat. We have reason to believe that other improvements of the surface of this area may be effected at a cheap rate so as to adapt it more completely for the reception and quick discharge of rain water.

Besides facilities for the rapid removal of the surplus moisture from the land, there are required for the service in question, powers in respect to land under cul-

tivation (if any need be taken) or to land which may be brought under cultivation, so as to restrain the cultivator from courses which would deteriorate the quality of the water, as from the use of lime, or from some modes of manuring. The well through which the water supply for Farnham is delivered is a permeable brick well in the midst of a garden. Some traces of the manure of the garden were, after a heavy rain, detected in the well.

For the facilitation of the requisite works, and the avoidance of delay, disputes, and litigation, the most satisfactory course to all parties would probably be to give a fair money compensation for the manorial and common rights, and to take them as for the public under an Enclosure Act, and then relet them with the requisite restrictions as to water rights and cultivation, putting the rent in reduction of the public charges.

We may here venture a general observation, which does not appear to be required as respects the particular tract of land under immediate consideration, that drainage and the application of manures are so far susceptible of improvement as to remove all apprehension of such waste from the washing away of manures through the land drains, as at present occurs from the washing away of the solid manures from the surface of undrained land. It would, however, be practicable, where heavy manuring may still be required, to divert for a time from the town water service, the surplus water from lands.

We entertain no doubt from the indications elicited by Professor Way, that clay lands may by skill be extensively applied as gathering grounds to the advantage alike of the land and of the town population; but clay lands, being usually under some sort of cultivation, are rendered ineligible by the difficulty of adjusting legal rights, powers, and terms in relation to them.

As a foundation for proximate estimates, plans have been got out by our engineering inspectors for extensive covered reservoirs, and for the conveyance of the water

in deep conduits, also covered. They estimate the total expense of storing and bringing to the metropolis this new and improved supply, inclusive of reasonable compensation for waste land for the reservoirs, at little more than one million sterling. We fully believe, that two years' saving from the use of the purer water would fully repay this portion of the outlay.

Various detailed estimates have been made at our instance of the expense of distributory apparatus, including service-pipes for carrying constant supplies of water into tenements of the poorest classes, as part of works for sanitary improvement requisite for the worst conditioned places; estimates have also been made of the expense of distributory apparatus for the supply of houses of all classes above the poorest. The result is, the confident assurance of all our engineering inspectors, supported by other concurrent practical testimony, that an entirely new supply of the softest water may be brought to the metropolis, pure, filtered, and well aërated, and may be delivered into every house in the metropolis on a constant supply, unlimited in quantity, for drinking, for culinary and other domestic purposes, for baths and for washing, at an average original rent-charge, inclusive of the expense of the tenant's supply-pipe and tap, of 2*d.* per week per tenement.

With these results, which, with adequate powers, could unquestionably be obtained, the metropolis would be placed in a condition equal in respect to the quality of its supplies of water, and superior in respect to their distribution, to any metropolis or city in the ancient or the modern world.

Having displayed the evidence in relation to the means of obtaining a new supply of water of superior purity, in substitution for the hard and polluted water at present delivered, we need only state that the new supply of soft water appears to be in quantity commensurate to the domestic wants of the metropolis and moreover to suffice for new and improved applications of considerable importance.

II. This brings us to the *second* head of our inquiry, viz., as to the mode of distribution now adopted, and as to the influence of the mode of distribution upon the quantity of water required for the metropolis.

The accounts of the medical inspectors and witnesses, of the consequences of keeping polluted water in small vessels in close and crowded rooms occupied by the poorer classes, their quarrels round stand pipes when the intermittent supplies of water are on, their taking water from tidal ditches which are used as sewers, with much evidence of the same tenor as that of Dr. H. Gavin and Mr. Bowie, already recited, might be presented, as confirmatory of the unanimous resolutions of parochial vestries and meetings throughout the metropolis, that the present supplies of water are deficient in quantity as well as objectionable in quality. At a recent meeting of the Consolidated Metropolitan Commission of Sewers, the necessity of additional supplies of water was generally assumed as an admitted fact. Captain Vetch, who has paid much attention to the subject, had prepared a paper on the best means of supplying the deficiency.

The determination of the quantities required involves, however, the consideration of the mode of distribution for the house or domestic service; and also the means for the removal of polluted or waste water after it has been used. One large source of demand for increased supplies being for the flushing of sewers and the cleansing of house drains, the present and proposed construction and action of these sewers and drains is necessarily involved in the determination of the gross quantity of water which may be required for the service of the metropolis.

At the opening of the present investigation, one of the first steps was to examine the returns made by the several companies—as to the quantities of water which they actually delivered. In 1832, a return was made by the several metropolitan Companies of the average quantity of water daily delivered "per house or building" to those whom they supplied. Since 1832,

the number of their tenants has largely increased. The summary of the Companies' returns of the quantities of water delivered during the last year, which we have submitted in detail, is given in the following table, by the side of the returns as they gave them for 1833.

COMPANIES.	Average Quantity delivered Daily to each House or Building.	
	In 1833.	In 1849.
	Gallons.	Gallons.
New River . . .	241	170
East London . .	120½	156
Chelsea	168	187
Grand Junction . .	350	255
West Middlesex. .	185	136
Southwark* . . .	156	176
South London . .	100	
Lambeth. . . .	124	132

* Now incorporated under the name of the "Southwark and Vauxhall Water Company."

It appeared to us in the examination of these returns, as we apprehend that it would appear on consideration to any one who had visited the houses of the poorer classes, where they are provided with pipe-water supplies, that an average consumption of such a quantity of water as 50 pailfuls per diem, was utterly irreconcilable with their known habits or requirements. One-hundred and forty gallons of water weigh 1,400 lbs., or more than half a ton, which it certainly exceeds the power of one servant of all work to carry about a middle class house from day to day. In the higher class of houses, a consumption of more than 100 pailsful of water from day to day, according to the returns, appeared to be impossible.

On expressing to several of the principal officers of the Companies some *primâ facie* doubts on the subject, they at that time declared their belief, not only of the correctness of the returns as to the quantity of water delivered, but of its actual consumption. The Secretary of one of the Companies, speaking of the habits of the labouring classes, stated that only persons

practically acquainted with them, and who had to go as much amongst them as the Companies' officers and servants, could be aware how they threw about water in washing floors and yards, and what quantities they generally used. Occasionally, no doubt, there was waste, but it was repressed when discovered, and was believed really not to amount to much. The Directors, as well as the officers of the Companies, appeared to be perfectly satisfied that this was the true state of the facts. Mr. Mylne, the engineer to the New River Company, in his evidence before the Commissioners of Inquiry into the means of Improving the Health of Towns, when questioned as to the practicability of a constant system of supply, did not deny its practicability as an engineering fact, but he then intimated that the Company had already experienced the need of additional supplies of water, and assumed, that the change of system spoken of must augment that necessity. When more recently inquiries were made by the Commissioners of Sewers for the Corporation of London, on the practicability of giving constant or additional supplies, he on the part of the Company, still pointed out the necessity of increased powers for meeting the requirements of the case, and obtaining additional supplies, and the Company have now a Bill before Parliament to give them fresh powers for this purpose. As we have already stated, almost all the new schemes of water supply for the metropolis are based, as one main condition, on the necessity of supplies of increased quantities in addition to the gross quantity at present delivered. Mr. James Walker, Mr. Brunel, and Mr. William Cubitt, the engineers, express, as a decided opinion, that it would be desirable to apply a portion of the Thames itself, or to bring the River Colne or the River Lea into the metropolis, for the flushing of sewers, like the use of the Alster, for flushing the sewers of Hamburgh.

Such being the impression of the professional engineers, and of the parochial and other local and administrative bodies to whom they appealed, and whose

support they have obtained, it has appeared to us to be due to the public, as well as to the existing Companies, to examine, as closely as practicable, the correctness of their allegations as to the quantities of water actually supplied, and further, to inquire what are the real requirements of the population.

With this view, and for the service of the drainage works of the metropolis, with the consent of the Metropolitan Court of Sewers, various trial gaugings have been made by their surveyors, to ascertain in periods when there was no rainfall, what was the quantity of water discharged through the sewers, from houses supplied with pipe water.

There was much difficulty in obtaining blocks of houses draining from what is technically called "dead ends," but such blocks were obtained in different districts of houses unconnected with other districts or main lines of sewers, where all, or nearly all the houses were supplied with water on the same days.

As a specimen, we may state the result of the gaugings of one large block of nearly 1,200 houses, in Earl-street, on Lord Portman's estate, near the Regent's Park. Some of these houses were of the higher, and many of the poorer class, but the average might be stated to be of the middle class, and to present a fair example of an urban population. The drainage of all these houses was discharged through one main sewer. The run of water through this sewer was carefully watched and gauged every hour during the night as well as the day, on days when the water was on, that is to say, when the intermittent supplies were delivered, from the mains of the West Middlesex Company, and also on the ordinary days, when the consumption of the houses was from butts and cisterns into which the intermittent supplies were delivered. The gaugings were continued during periods when there was no rainfall, and when only the pipe water could pass through the sewer, as well as on days of rainfall. The gaugings of the discharge of waste water into the sewer, were checked by gaugings of the consumption of water from

the butts and cisterns, during the intervals of the delivery of the supplies by the Company. Mr. Lovick, the surveyor, who executed the directions given for the gaugings, and whose rigid accuracy,and competency for the work are generally acknowledged, has made important sets of diagrams displaying the results.

It appeared that the average quantity discharged per diem through the sewers, was 44½ gallons per house. The average consumption as ascertained from the gaugings of the butts and cisterns was, however, $51\frac{1}{2}$ gallons per house per diem.

It appeared that on ordinary days, not less than one-eighth of the water consumed was lost by filtration through the permeable brick house-drains. The block of houses was densely peopled, there being rather more than 9 persons to each house, and the consumption of water was 5·7 gallons per head per diem.

Measured by the asserted average delivery of the Companies, the consumption would be 20 gallons per head on the population. But it appeared, that on the days when the intermittent supplies of water were "on" the quantity discharged per diem was 209 gallons per house. There was no doubt, however, that from the defects of the present system of permeable brick-drains and sewers, and from the loss in cesspools, the quantity really delivered was greater than the gaugings represented. Hence, the waste in this district, from defects in the house apparatus of distribution, incident to an intermittent system of supply; was, on the water days, three and three-quarter times greater than the consumption on those days. The waste, during the whole week was not less than three-fifths of the actual quantity consumed.

Thus the waste in that one district, was at the rate of upwards of four and a half millions of cubic feet per annum, and would cover to the depth of nearly 30 inches, the whole area, including roads and houses, draining into the outlet sewer. Upon that area, the waste alone largely exceeds the annual rainfall.

Notwithstanding this waste of water, in consequence of the defective construction of house-drains and sewers the flow did not prevent, but only retarded accumulations in them; the accumulations went on at the rate of 6,000 cubic feet in 31 days in the sewers alone; and the deposits in the house drains must have been very considerable.

Mr. Roe, the chief surveyor, gauged the run of waste water from houses of the highest class, all of which would have water-closets, many of them, also, baths and stables; and the run of water from them did not average more than 76 gallons per diem, on the ordinary days when the water was not on. In third-rate streets the run of water was about 45 gallons per house per diem.

What is the rate of discharge (in gallons) in the sewers in the street you mentioned in the New River Company's district, when the water was on, and when there was no rain-fall?—The greatest flow observed was 160 gallons per minute.

What was the rate of run when the water is not on, and when there was no rain-fall?—Four gallons per minute.

He had taken gaugings of the flow of water in one large main outfall, the river Fleet, which drains a very considerable proportion of the north side of the metropolis. He was asked—

What districts does the Fleet drain?—A large portion of St. Pancras; a portion of Islington; St. James, Clerkenwell; and part of St. Andrew, Holborn, and other districts below the point of observation.

In the River Fleet what was the rate of run at periods of time when there was no rain, and in days when the water was known to be on in the district?—The average rate of run during a month of dry weather, at the time when the flow was affected by the water-supply in the district, was 1,738 gallons per minute.

What is the rate of run at like periods of time in dry weather, and when the water is not on?—The water-supply appears to be on every day (except Sunday) in some portion or other of the district draining to the Fleet, parts of which are supplied by the Hampstead Water Works, and others by the New River. The rate of run, when not affected by the supply being on, was 756 gallons per minute.

Mr. Gotto, a surveyor who had made observations in some of the north-eastern districts, was examined.

What is the average consumption per house where supplied from butts, the supply being on alternate days?—The average quantity of water actually consumed per house is about 9½ cubic feet in the lower neighbourhoods, such as that under consideration, and where each house contains 10 persons on an average. This is ascertained by selecting a number of houses where the water-butts are emptied before the next supply fills them. But the houses in such places have not all cisterns; most of them procure their water from the stand-pipe in stone jars, many others have pails and kettles, but few have cisterns or water-butts.

Did you find that the butts were not emptied on the second day?—103 water-butts and cisterns out of 141 which have been examined in this place were not emptied before the next supply came in.

Where the houses were drained could you find an average discharge of water?—I have had several opportunities of making such observations. In the first instance alluded to previously at Goulston-street, standing on an area of 223 square yards, six houses are supplied with 150 cubic feet of water by the New River Company daily, for about 1½ hour, into 5 water-butts, containing each 7 cubic feet, or together 35 cubic feet. The average discharge here through the 9-inch stoneware drain, during the time the water is being delivered, is 55 cubic feet per hour, or 82½ cubic feet during the time of supply, and about 1 cubic foot per hour during the remainder of the day. This was only the ordinary flow from the houses, and in fine weather.

Observation No. 2.—About 380 houses, draining into a 12-inch pipe laid along the towing-path of the Regent's Canal, near the Caledonian-road:—

DATE.	Total Discharge in 24 hours.	Discharge per House in 24 hours.	Greatest Flow per hour.	Least Flow per hour.
1850.	Gallons.	Gallons.	Gallons.	Gallons.
Thursday, January 10, not a water-day	18,927	50	4,200 (From 1 to 2 P.M.)	252 (From 6 to 7 A.M.)
Friday, January 11, water-day	26,139	85	12,600 (From 10 to 11 A.M.)	252 (From 6 to 7 A.M.)
Saturday, January 12, water-day	39,669	104	12,600 (From 7 to 8 A.M. from 3 to 4 P.M.)	186 (From 6 to 7 A.M.)
Monday, January 14, not a water-day	14,169	40	3,150 (From 9 to 10 A.M.)	140 (From 6 to 7 A.M.)

The greatest depth of water in the 12-inch pipe during these experiments was 3 inches, but little more than one-third of its sectional area.

Mr. Gotto adds:—

An instance of the waste of water under the present system may be exemplified by an examination I have made of the flow of water through a pipe-sewer in Whitechapel.

The water is on for about 1½ hour each day. There is about 900 gallons delivered into the five water-butts that supply the six houses, draining through a 9-inch pipe-sewer. The water-butts hold together 210 gallons, and all the rest runs to waste; 540 gallons of this is found by gauging to pass away through the drain.

In another instance which has come under my notice in John-street, Edgware-road, six houses having water closets and cisterns are supplied by the West Middlesex Water Company. The cisterns together, contain before the water is newly turned on, 696 gallons; and after the water is turned off and they are full, 1,086 gallons; the quantity therefore used and passing through the sewer in one or two days of interval is 396 gallons; but on the water day 1,188 gallons passed through, so that there was 396 gallons used and 1,005 gallons wasted in two days. The average quantity of water actually used in this place is about 5 gallons per day for each person. In Park-place, St. James', the Grand Junction Water Company supplies nine houses (one a large mansion) with water, and during the hour of supply there passes through the 12-inch sewer-pipe from these houses 4,320 gallons, while the quantity actually used per day and passing through the sewer when the water is not laid on is 3,660 gallons, the quantity wasted being about as much as that used.

The enormous fallacies on which such waste has been so long continued, and under the influence of which it is proposed to invest new capital, might have been corrected by a view of the butts and receptacles for pipe water attached to the houses supplied. In the poorer districts they are not one-third, and often not one-fourth the capacity requisite to contain the water which it has been assumed they receive, and which is said to be used. In respect to the suburban houses of the more easterly districts, Mr. Morris, one of the surveyors acting under the Metropolitan Sewers Commission, was asked:—

What sized butts are usually used for this poor class of houses? —4 feet by 2 or thereabouts, holding about 54 gallons.

From what you have observed of the population, do you think they use the whole of the contents of such a butt each day?—I think not so much.

Then if there were a constant supply of water carried into each

house, there would not be more than 40 or 50 gallons used each day?—I think not.

It is stated that in the district about 200 gallons per house is pumped in three times a-week. Does it not follow from your statement of the sizes of the butts and the quantities consumed, that the greater proportion of the water now pumped into the district must be pumped to waste?—Yes; quite one half: all parties coincide in saying that full one half is now wasted.

Mr. Grant, the surveyor to the Metropolitan Commission of Sewers, acting for the southern district of the metropolis, which is supplied with water by the Southwark and Vauxhall Company, declares, upon extensive and careful observation, that that Company at present pumps into the district a quantity, considerably more than the total rainfall on the area, and 100 gallons per house in addition to the rainfall.

The general correctness of these observations is now indeed admitted by the officers of the chief Companies. In the conclusion they establish as to the actual consumption, they are very nearly in accordance with the observations conducted by Mr. Lovick.

Mr. Quick, the acting engineer to the Southwark and Vauxhall Company, and consulting engineer to the Grand Junction Company, being examined on this topic, was asked,—

What is the quantity pumped per diem by the Southwark and Vauxhall Company?—Between six and seven millions of gallons, or a daily average throughout the year of 6,011,225 gallons.

To how many separate houses and buildings?—35,511.

What do you estimate as the average quantity delivered to each house or building per diem?—143 gallons daily throughout the year for domestic use, being 22 gallons per head; or 169 gallons, which includes the supplies to railways, manufactories, road-watering, &c., being 26 gallons per head.

Are not the houses on the south side, or in the Southwark and Vauxhall district (on the average) of a much lower class in rental and condition than those of the Grand Junction?—Certainly, very greatly so; but it is difficult to draw a comparison between the districts.

Do you know the average size of butts and cisterns to the lower class of dwellings?—They are very various; ranging from a small pork-tierce of three or four gallons, to an 18, 54, or 63-gallon cask, but seldom approaching to the latter. Cisterns are very rare

in small houses, and when put up do not contain more than 40 to 50 gallons.

Are not butts of the size of 100 gallons very rare in the Southwark district?—Yes; there are very few of the smaller class of six or eight-roomed houses that have above a 63-gallon cask; but houses of a better description will have receptacles that contain between 100 and 200 gallons.

Have you ever had an opportunity of gauging the contents of butts, and the quantities of water consumed?—I have lately made some experiments, and find that the butts of four, six, and eight-roomed houses, containing 40, 50, and 63 gallons respectively, are, on the average, about half emptied in a day; so that when the water is turned on only half a butt would be required by 19 out of 20 houses; but it generally happens that the twentieth is a baker or butcher, or perhaps a public-house, with a butt or cistern in an elevated position, for the convenience of his business, or the saving of room; and to satisfy the wants of this one tenant the water has to be kept on three or four times longer than would be sufficient for the ordinary supply; and the waste going on the whole time from the adjoining houses, brings up the average daily supply to 143 gallons for each house.

Then you think that the butts served them well, as far as your observation went, when the supply was given on alternate days?—Yes; but not so well as now, with the exception of the very poorest districts, in which, when the Company supplied on alternate days, butts were provided; but since the water has been turned on at a certain hour every day in the week, many take their chance of filling any vessel they may possess during the time it is on. The daily supply has been afforded by the Company for nearly two years.

Has your number of customers increased in a greater ratio since the daily supply has been given?—Not more than previously, as the same amount of water in the aggregate was allowed to each house as at the present time; the only difference being that it is now turned on for one hour daily, in place of two hours every other day.

Have you seen a set of gaugings made on a block of 1300 houses, on the north side of the Thames, which were supplied with water, and where it was proved that the quantity of water daily consumed from the cisterns was 51 gallons per house?—I have; and I believe that quantity to be a fair average of the positive consumption for the middling classes of houses, and it quite accords with my own observation.

It has been stated that the quantity of water now delivered into the metropolis is nearly forty-five millions

of gallons per diem. From the gaugings of the run of water in the sewers, from the examination of the works of the Water Companies, and from the evidence respecting them collected by Mr. Cresy, our inspecting engineer, we believe these returns to be, on the whole, correct. Believing this to be so, it follows, from the various examinations of the quantity of water actually consumed, that nearly thirty millions of gallons are daily pumped into the metropolis in waste. As applied to the excessive water supply, the term "*waste*" has been used; but if this large volume of water could only be considered as so much wasted, it would represent a certain amount of loss in money alone; borne by the public, it is true, and consequently a grievance, requiring at the hands of the Legislature a corrective remedy. But the actual results are far worse; this water is not only waste, but a positive injury to the landlord, as well as to the tenant; to the landlord, by creating undue damp, and thereby injuring his property; to the tenant, by saturating the whole subsoil with fluid refuse, tending to generate foul and highly dangerous gases; as also, by rendering the basement floors, the walls, and yards unduly damp, producing all those ill effects known to exist in connexion with swampy undrained districts. The excess of wet and damp has intervals of abatement in summer-time, and during dry weather: but this waste keeps up the wet and damp during the intervals, and aggravates them during the periods of rainfall. Mr. Quick thus testifies to the effects in Surrey:—

In that particular case, and in others also, the general conclusion has been stated, that the quantity of water wasted is absolutely three times greater than the water consumed?—I believe that to be the case; generally I know it to be so in the Southwark and Vauxhall district.

Then the only difference is, that on the north side the water is silently conducted through a waste-pipe from the cistern to a drain, and on the south side is allowed to run over the sides of a butt and saturate the earth?—Yes, and in many cases it causes the most serious inconvenience to persons situated on lower levels than their neighbours, by flooding them every time the water is turned on, and it is one of the arrangements that would require the most serious consideration in any new system of supply.

So full of wet was much of the lower district of the south side of the river, from the defective drainage, so defective were such drainage works as had been constructed, that in opening trenches to lay down water-pipes, the workmen, in passing those works, were obliged to exercise great care to prevent the saturated earth falling in, and letting out the side of the brick drains and sewers, with their accumulations of fœtid contents.

Mr. Cresy, jun., one of the Surveyors of the Metropolitan Commissioners of Sewers for the East Surrey district, was asked—

Do you find in that district any of the water supplied to the houses to escape in waste?—A very large proportion; we have had no accurate gaugings taken, but noticing the time during which the water is on, the bore of the supply pipes, and the capacity of the cisterns and vessels provided for its reception, I should say that from two-fifths to one-half the quantity supplied is in many cases wasted.

What is the effect of this on the sites of habitations?—A most pernicious one; the wet soaks the whole of the soil, and has no means of escape, the subsoil being water-logged twice in twenty-four hours by the tide, and from the great portion of the district lying so remarkably low, it can only drain off for an hour before and an hour after low water.

Mr. Grant was asked, in relation to the same district—

Are the houses damp or water-logged?—There are many in Wellington-street and Rose-court which have water standing under the floor, and sometimes over it. The occupants pump it out when it gets over the floor.

At this time, when there has been scarcely any rainfall, except for one day for nearly six weeks, when a site would in rural districts unsupplied with pipe water be dry, what is the actual condition of the sites of the houses in the lower and worst drained parts of your districts?—The subsoil and foundations are surcharged with water. I have had lately to examine the premises of a large charitable institution in a district deficient of drainage, in which from the waste surface water on one side, and the soakage of cesspools on the other, the occupants of every room complained of the damp which affected the walls to a height of 2 or 3 feet.

Mr. Gotto, in the course of his examination on the subject of the particular houses in Whitechapel, where

the consumption of water was gauged to test the waste, was asked:—

Did you find the foundation of the houses very damp there?—The lower floors of the houses thus supplied with water, and having no drainage, are very damp, especially where stand-pipes are used to deliver the water. In some places the yards are completely flooded in consequence. And this dampness, besides aiding in the production of sickness, hastens the decay of house property, and is thus the cause of much permanent damage. The subjects of water supply and drainage are inseparably connected: water should only be very cautiously administered where no drainage exists; and where houses are supplied with water there should be drains to carry it away, and both should be under one superintending jurisdiction.

The answers by some of the Companies themselves display the consequences of the separate introduction of supplies of water into houses without any care or adaptation of means for its removal, after it has been used.

New River Company, in answer to question 14—

How many courts and houses are there in your district that cannot be supplied for want of drains to carry off the water if it were laid on?—None; as the Company have never regarded the want of drains as a reason for not laying on water.

The Southwark and Vauxhall Company in answer to question 18—

How many courts and houses are there in your district that cannot be supplied for want of drains to carry off the water if it were laid on?—It is difficult to produce an answer to this question; but many owners of small property state that they would have the water laid on if there was any way in which the waste could be carried off.

The same Company, in answer to a question previously put to them by the Metropolitan Commissioners of Sewers, "What regulations have you as to butts and "cisterns?" reply—

By section 101 of the Company's Act, 4 and 5 Wm. IV., cap. 79, no person is empowered to demand a supply of water from the Company unless he provide a sufficient cistern or cisterns fitted with a proper ball-cock for its reception.

By section 97 a penalty not exceeding *5l.* is payable for waste of water occasioned by neglect in keeping pipes, ball-cocks, &c. in order, and the Company's officers have power to enter to ascertain whether such waste exists. These powers would seem to be

sufficient, but so general is the reluctance on the part of the proprietors of small houses to provide proper accommodation for benefiting by the supply of water, that the Company find it practically impossible to enforce the regulations prescribed by the Act. In the Company's district there are some thousand houses without cisterns, butts, or vessels of any kind for receiving the water, and yet more without stop-cocks, or the means of shutting off the supply, so that not only is the water wasted, but its very abundance produces evil by saturating the ground and making the houses so damp as to be unfit for habitation.

We must here stay to note the sanitary evils of the flooding with the excess of pipe water, equal to more than double the annual rainfall thrown upon the low lying and ill-drained districts.

Although we could find no evidence to justify the supposition that the aggravated effects of the cholera, in the lower districts, was to be attributed to persons drinking pipe water, which, in fact, very few people do habitually drink; the water in cases where the mortality was traced to this source being, as already shown, well water polluted by bad drainage,—yet there can be no doubt that this waste and the consequent flooding must have greatly aggravated the natural damp in those districts where, according to the statement of experienced medical officers, they are sure in damp weather to find one species or other of epidemic disease prevailing amongst the population.

We need not repeat that bad drainage is one of several causes of epidemic disease, and although some high lying districts, such as St. Giles's, are worse drained and in most respects worse conditioned than many lower districts, nevertheless, on taking wide averages, the prevalence of epidemic disease is found to bear a proportion to the state of drainage, and of the excess of damp where other conditions are similar.

On dividing the metropolis into two great districts, the highest and the lowest, in relation to the Trinity high-water mark, we find that whilst in the highest districts at an average level of 54 feet above high-water mark, the proportion of deaths from fever was in 1838, 425; in the lower districts at an average level of 11

feet only above high-water mark, the deaths from fever were 1 in 255. In 1832, the deaths from cholera in the higher districts were only 1 in 551; in the low lying districts, they were 1 in 200. In 1849, in the higher districts the deaths from cholera were 1 in 347; in the lower districts 1 in 118. The last most severe visitation, observed a close relation to the differences of drainage level, for whilst, during the preceding attacks, the visitation was severest in some of the intermediate districts, on dividing the whole of the metropolis into three districts, the highest averaging 63 feet above high-water mark; the intermediate averaging 30 feet, and the lowest averaging 4 feet, we find that the deaths were in the highest 1 in 346; in the intermediate 1 in 256, and in the lowest 1 in 93.

TABLE showing the Deaths from Cholera in the Metropolis, in 1832 and 1849, and the Deaths from Fever in 1838; also the Average Elevation of the Inhabited Districts above Trinity High Water-mark, and the Average Proportion of Deaths, in two Classes.

CLASS.	DISTRICTS.	Number of Feet of Ground above High Water-mark.	Deaths from Fever, in 1838, to Population.	Deaths from Cholera, in 1832, to Population.	Deaths from Cholera, in 1849, to Population.	Increase or Decrease in 1849 with 1832.	
						Increase.	Decrease.
			One in	One in	One in		
LOWEST	1. Newington . . .	2	668	223	69	In.	..
	2. Rotherhithe . .	0	302	678	37	In.	..
	3. Bermondsey . .	0	206	142	52	In.	..
	4. St. George, Southwark	0	321	91	60	In.	..
	5. St. Olave and St. Saviour's . .	2	160	114	58	In.	..
	6. Westminster . .	2	260	384	141	In.	..
	7. Lambeth . . .	3	396	261	87	In.	..
	8. Camberwell . .	4	638	264	98	In.	..
	9. Greenwich. . .	8	304	417	123	In.	..
	10. Poplar	10	412	234	111	In.	..
	11. Chelsea . . .	12	..	..	183	..	..
	12. St. George-in-the-East	15	208	313	205	In.	..
	13. Stepney . . .	16	288	171	205	..	De.
	14. Wandsworth . .	22	..	..	90	..	..
	15. West London . .	28	..	..	67	..	..
	16. Whitechapel . .	28	165	113	141	..	De.
	17. Lewisham . . .	28	..	..	276	..	..
	Average . .	11	255	200	118	..	..

Table showing the Deaths from Cholera in the Metropolis—*continued.*

CLASS.	DISTRICTS.	Number of Feet of Ground above High Water-mark.	Deaths from Fever, in 1838, to Population.	Deaths from Cholera, in 1832, to Population.	Deaths from Cholera, in 1849, to Population.	Increase or Decrease in 1849 with 1832.	
						Increase.	Decrease.
			One in	One in	One in		
HIGHEST	18. St. George, Hanover-square	34	421	786	569	In.	..
	19. Bethnal Green	36	239	365	106	In.	..
	20. St. Martin-in-the-Fields	35	352	385	285	In.	..
	21. City of London	38	507	155	267	..	De.
	22. East London	42	..	..	216	..	..
	23. St. James, Westminster	43	781	385	640	..	De.
	24. Kensington	44	522	561	370	In.	..
	25. Shoreditch	48	256	1,203	121	In.	..
	26. St. Luke	48	458	395	277	In.	..
	27. Strand	50	463	270	274	..	De.
	28. Holborn	53	227	594	281	In.	..
	29. Hackney	55	999	916	344	In.	..
	30. Clerkenwell	63	478	733	530	In.	..
	31. St. Giles	68	261	189	194	..	De.
	32. St. Pancras	80	269	933	435	In.	..
	33. Islington	88	518	957	394	In.	..
	34. Marylebone	100	479	546	588	..	De.
	Average	54	425	551	347	..	..

Though we know the excess of damp from simple moisture to be productive of evil, of which we may expect to see the results displayed on a large scale, yet in the lower district, the excess of surface water is thrown upon ground imbued with cesspool matter, which it causes to permeate through the stratum into wells and saturate basement walls and foundations. The connexion is denoted by the frequent declaration of the inmates that when the water is on, bad smells arise. As preparatory to the consideration of the necessity of combined works for the relief of the metropolis, we would submit for consideration the actual returns from three parishes as examples, and by no means unfavourable ones of still wider districts, displaying the position of the water supply in relation to the cesspools and other sources of impurity.

These returns were obtained through the Consoli-

dated Commission of Sewers by means of house-to-house inquiries answered in writing by the householders themselves, with a view to their serving as data for future guidance, for combined works of relief. The returns may be submitted as favourable, inasmuch as the answers were filled in chiefly by tenants of the middle and higher classes of houses; the poorer classes of tenants, the occupiers of weekly lodgings, being frequently incompetent to write down the answers, or otherwise impeded in giving them. But, when the returns show, as is the case in the populous parish of St. George the Martyr, Southwark, that 48 per cent. of the water-butts are near a privy, and that privy a cesspool; the fact gives our medical inspectors more extensive information, and deeper ground for apprehension as to the quality of the water supply, than is possessed and felt by the consumers themselves. When we find that there are wells on or near the premises, and the householders return that 48 per cent. of them are perceptibly foul or tainted, and when the same returns show that 82 per cent. of the houses have cesspools, where we know that the site is for the most part one of permeable gravel, we are very certain that the pollution of the well water must be more frequent and general than the inhabitants themselves are aware of, and that the pollutions noticed in the returns are those only which have reached a comparatively high degree of offensiveness. And so in respect to house drainage, where we find, as stated in returns by householders, that more than 18 per cent. of the houses have constantly stagnant water upon the premises, and that an equal number of them are flooded in times of storms; knowing that the district is below high water mark, we are aware that the ponding up the sewer water by an intermittent system of drainage is productive of yet more extensively pernicious effects than are denoted in the return which represents that more than 52 per cent. of the houses are always damp in the lower parts, that 45 per cent. of the house drains emit offensive smells, and that in 27 per cent. of the

premises, the occupiers are subjected to effluvia arising from their neighbours' premises, as well as from their own. Our medical inspectors on going into houses in these districts early in the morning, or before the shutters or doors are opened, are struck with the offensive condition of the air within the houses, and to the foul smells, of which the inhabitants themselves appear to be insensible.

Observing that the parish of St. James has less than half the number of cesspools existing in the parish of St. George the Martyr, we turn to the records of epidemic disease and of premature and preventible mortality for these parishes with the certainty that we shall find large proportionate differences; and we do so. We find that in 1841, the deaths from ordinary epidemic diseases in the parish of St. George the Martyr, Southwark, were in proportion to the population double the amount of deaths from the same causes in the less ill-conditioned parish of St. James's. Yet in one year (1839) out of 752 deaths in the latter parish, 118 were deaths from epidemic disease. In the parish of St. James there was an excess in number during that year of 251 deaths, as compared with the rate of mortality in a better-conditioned suburban district, (Camberwell); the individuals swept away had the duration of their lives, as measured by the Camberwell average, shortened by 13 years; 40 per cent. had been swept away before attaining their fifth year. In 1832, in the parish of St. James, the deaths from cholera were 1 in 385 of the population, while in St. George the Martyr, they were 1 in 91. During the last visitation, the deaths from cholera were 1 in 60 of the population in St. George the Martyr, whilst in St. James's Westminster, they were 1 in 644. The deaths from cholera in St. Ann's Soho, were 1 in 336, but the general mortality of the last mentioned parish is not distinguished in the Registrar General's returns.

RESULTS of a HOUSE-TO-HOUSE INQUIRY in the Parishes of ST. GEORGE THE MARTYR, Southwark, ST. ANN'S, Soho, and ST. JAMES'S, as to the state of the Works of Water Supply and Drainage.

CONDITION OF THE HOUSES.	Answers Affirmative	PARISHES. St. George the Martyr, Southwark.	St. Ann's, Soho.	St. James's.
From which replies have been received	Number.	5,713	1,339	2,960
With supply of Water—				
To the house or premises	Per cent.	80·97	95·56	96·48
Near the privy	,,	48·87	38·99	43·42
Butts or cisterns, covered	Number.	1,879	776	1,621
,, uncovered	,,	2,074	294	393
With a sink	Per cent.	48·31	89·29	86·70
With a Well—				
On or near premises	,,	5·32	13·97	13·85
Well tainted or foul	,,	46·92	3·71	7·36
Houses damp in lower parts	,,	52·13	30·90	26·67
Houses with stagnant water on premises	,,	18·54	7·95	2·95
Houses flooded in times of storm	,,	18·15	5·04	4·05
Houses with Drain—				
To premises	,,	87·56	97·12	96·42
Houses with drains emitting offensive smells	,,	45·11	37·62	21·41
Houses with drains stopped at times	,,	22·37	28·50	13·97
Houses with dust-bin	,,	42·69	92·34	89·80
Houses receiving offensive smells from adjoining premises	,,	27·82	22·54	16·74
Houses with privy	,,	97·03	70·63	62·53
Houses with cesspool	,,	82·12	47·27	36·62
Houses with water-closet	,,	10·06	45·99	65·86

The set of house-to-house queries comprehended some as to the numbers of persons who had been ill in the house. So far as answers were given, all points considered, they were in coincidence with the condition of the districts as displayed in the returns.

		St. George, the Martyr.	St. Ann's, Soho.	St. James, Westminster.
Houses giving affirmative answers in cases of illness to total replies received on this head	Per cent.	28·25	24·58	14·16
Persons ill in each house	No.	2·21	2·05	1·83
Persons occupying each house where illness has occurred	No.	7·47	12·34	11·56
Proportion of persons ill during the year to occupants of houses where illness has occurred	Per cent.	29·65	16·64	15·88

These facts display only in part the consequences of proceeding in ignorance or disregard of the fact, that

works to carry away waste pipe water must, in a town, form part of, and be arranged and maintained in harmony with, the works to bring in water. It follows that they should be executed and maintained under one and the same administrative direction. Although these principles are fully recognized and provided for throughout the Public Health Act, they are not recognized in the water schemes for the metropolis, where the importance of combination increases with the magnitude of the works required, and the gravity of the evils to be dealt with. These facts display the real state of information, on which large advances of capital are called for and engaged to be forthcoming, with high names ready to sanction the applications, and local authorities ready to pledge local rates for their payment.

One of the most important steps towards the prevention of disease is the abolition of all cesspools. For the apparatus to be used in substitution of cesspools, it is estimated that an additional supply of about five gallons per house would be required. This would augment the present daily average consumption to 55 gallons per house.

From such inquiries as we have made, we believe that a consumption of six or seven gallons per head, or fifty gallons per house, by the labouring classes, would be a great increase indeed on their present actual consumption of water. We hope and believe, that with the improvement in the quality and distribution of supplies, there would be such an increase in the domestic consumption of all classes, and particularly for personal ablution. But all this prospective improvement in cleanliness and increase of domestic comfort, and the larger consumption of water involved in the change, must depend mainly on the completeness of administrative arrangements for the extension of service-pipes and sinks, waste-pipes, and drains, into the dwellings of the labouring classes.

In the preparation of no one of the new schemes does the least idea appear to have been entertained of the pollutions arising from the most widely-spread apparatus,—that for house-distribution—though these pollutions are really greater than those arising from the wrong selection

of the water, or its wrong treatment at its source. Yet we have practical examples to show, that if the sources were changed for the better, without improving the mode of house-distribution, the sanitary benefits of the outlay would be extremely doubtful. We cite the following facts in illustration, from a letter to a member of this Board, by a gentleman of eminent scientific acquirements, in New York, U. S.

"The necessity of the harmonious action of the various means which conduce to a given end, is continually exemplified, when we attempt to gain such ends by any number of means less than the correlated whole. An illustration of this we have in the city of New York, which I have watched with much interest. The insufficient supply of water and its ill qualities, goaded the citizens into the magnificent undertaking of bringing the river Croton into our city from a distance of 40 miles. That is accomplished, and we have now great abundance of pure water. This abundance has led to its profuse use in sweltering summer days, in watering the streets, by means of the hose of private citizens. To understand the evil of this seeming good, it is necessary to state that, notwithstanding 'city ordinances' of most stringent 'words,' it is customary to throw refuse vegetables and other garbage into the streets. The evil of this uncleanly practice was but partially developed before the use of the Croton. Under our fierce sun the garbage soon became dry, and comparatively harmless; but now it is soaked hour after hour, as fast as it shows an approach to dryness, and is thus kept incessantly fermenting and putrefying, to the great annoyance of delicate olfactories and the deterioration of the common air.

"Then again the city, with probably the best natural advantages of any large city in the world for perfect drainage, is drained very imperfectly. Before the introduction of the Croton, the inhabitants had to obtain their supply of water from wells, sunk in all parts of the city; the continual pumping from which kept the ground somewhat drained, notwithstanding the universal use of cesspools and privies; but now, for lack of drainage, many sub-cellars have become covered with water, and a great number of basements and cellars have become damp. I am satisfied that all the citizens will be constrained in self defence, to become more cleanly in their streets, to resort to a thorough system of sewerage, to connect waste pipes or small sewers, instead of using cesspools, and to introduce water-closets communicating with the sewers, in place of the disgusting system of open sinks, now in general use. When these measures are adopted, the sanitary means conducive to cleanliness will be in harmony, and then, and not till then, shall we reap the full advantage of even the pure and copious Croton River. Indeed, until these correlative measures

are adopted, our abundant supply of water will conduce to many positive injuries."

Besides the great importance of the distributory apparatus in respect to the salubrity of the supplies, the very defects of the existing system of distribution in the metropolis, and the necessity for the construction and maintenance of tanks and cisterns to receive intermittent supplies, often occasion an expenditure by owners or occupiers equalling and exceeding the rates of charge for the water itself, high as they are. Thus, in new houses of the first class, the expense of cisterns, together with their supports and connected apparatus for water-supply and distribution, the greater part of which under a proper system would have been dispensed with, generally exceeds 100*l.* per house. At the usual rent or interest for such property, the annual charge for that outlay would be 6*l.* 10*s.* But to this must be added the plumber's annual bills for repairs of dilapidations, which will augment the charge to 9*l.* or 10*l.* per annum, apart from the occupation of space, the pollution of water, and the expense of filtration or of obtaining spring water; the charge for the water itself being between 5*l.* and 6*l.* per annum.

The burthens which the cost of unnecessary apparatus imposes on the improvement of dwellings for the labouring classes is shown in the expenses of the Metropolitan Association for that purpose. Mr. Gatliff, the secretary of that Association, being examined, was asked—

Will you state what was the expense, in the several blocks of buildings belonging to that Society, for laying on the water?—The expense of laying on the water, including cisterns, ball-cocks, extra pipes, &c., was—

	£.	*s.*	*d.*
In the buildings of the Association in the Old Pancras-road	517	0	0
In the dwelling for single men in Albert-street, Buxton-street, Spitalfields. .	92	0	0
Dwellings for families, in Albert-street, aforesaid	240	15	0
	£849	15	0

How much of this was due to the cisterns?—488*l.* 10*s.*

How much would it have been in the absence of cisterns?—In the absence of cisterns alone it would have been 361*l.* 5*s.* In the absence of cisterns, ball-cocks, extra pipes, &c., it would have been 92*l.* 15*s.*, unless other arrangements were necessary, upon which I should not presume to give an opinion. Our contractors consider stronger rising mains would be necessary.

Which proposition of the contractors, it may be observed by the way, is a common error. It has been proved that a stronger apparatus is requisite to resist the hydraulic shocks of an intermittent system which are more frequent than those occurring under a system of constant supply where proper screw-down taps are used; and these alone ought to be allowed both on account of their economy and superior qualities in use.

How much will the cisterns add to the rent, including in your estimate of the rent not only the original outlay, but calculating for wear and tear and dilapidation?—The cisterns, ball-cocks, extra pipes, and wear and tear of them will amount to 2*d.* per week for each set of rooms, as near as I can calculate, the rents of which vary from 3*s.* 6*d.* to 6*s.* 6*d.* per week.

Is the water delivered unfiltered?—I should term it so, though I have understood both companies have filtering-beds.

Do the tenants filter it themselves?—I do not think they do.

Have you considered the means of filtration for these houses?—I did with regard to the dwelling-house for single men, in Albert-street, Spitalfields. I have had Mauras's filtering-machine under consideration, and hope I shall yet succeed in bringing it into operation there.

What are the obstacles to the introduction of filters?—The expense to the class of tenants sought to be benefited by this Association.

The expense which the practice of the intermittent system of supply entails for the present pernicious internal apparatus, would suffice for the construction of other internal apparatus, adapted to the requirements of health and pleasure, as well as for real use; it would, for example, suffice not only for the distributory apparatus but for the construction of warm and cold water baths; and for return pipes to remove the waste water from each room; which would, in many establishments, save the daily labour of a servant in carrying up water into the different rooms, and removing thence the waste water.

In the dwellings recently erected by the Society for Improving the Condition of the Labouring Classes may be seen examples of the distributory apparatus—fountain earthenware wash-hand stands with return pipes—which may be constructed and maintained for the delivery of water into every room fresh and unpolluted.

For the further elucidation of the important question as to the proper mode of supply, it appeared to us that it would be useful to determine how far the results of our investigation, as to the actual consumption of water and extent of waste under the practice of the intermittent system in the metropolis, were conformable to the experience of those towns, now increasing in number, where the constant system is in actual operation. It sufficed to take a few examples.

At Preston, the average consumption of water was reported to be 50 gallons per diem per tenement, inclusive of supplies to a large proportion of factories, for steam power, and to a railway station.

It having been stated, that Mr. Quick, the engineer to the Vauxhall and Lambeth, and the Grand Junction Companies, had inspected those works for the satisfacfaction of his directors, he was asked—

Have you examined the system of constant supply as it is carried out in Preston?—I have.

Are the houses there, occupied by the labouring classes, on the whole of a better description than those occupied by the labouring classes in Lambeth and a large portion of Southwark?—Yes, both as to size and convenience; they are mostly provided with washhouses and sinks, and all the conveniences necessary for the comfort of a family.

The manager of the works in Preston stated in evidence that their average supply to 6,000 tenements was about 50 gallons per house per diem?—I have no doubt, from the great care that is taken to prevent waste, that the quantity named is correct.

There is a large proportion of manufactories included in that average of supply?—I was informed that was the average daily quantity used for all purposes of consumption, and that it was found to be sufficient for a population having larger demands for water than an average one.

Did you examine any other works than those at Preston where

the system of constant supply had been in action?—Yes, at Nottingham, where I questioned several of the housekeepers (both in the higher and lower portions of the town), to see if they were inconvenienced by the water being turned off at any time; I was informed that, before the water is turned off, a notice is sent from the Water Company to each tenant, with an intimation that the supply will be stopped from a certain time to a certain time. They know accordingly what quantity of water to draw off before the main is shut; but this happens so seldom, that they think nothing of it.

It may be added that this one-inch pipe now supplies 80 houses without any complaint of deficiency.

We addressed some queries to Mr. Coulthart, who had made an important Report on the sanitary condition of Ashton-under-Lyne (*vide* Health of Towns Report), to ascertain the precise quantity consumed in that town, where a constant supply, derived from the surface-drainage of some adjacent land, is in operation.

Mr. Coulthart states—

In answer to your inquiries on behalf of the Metropolitan Commissioners, I beg to annex a Table expressly compiled by me for your information, which exhibits the positive quantity of water consumed in 4,094 dwelling-houses in 168 hours, in May, 1847; and as the measurements connected with the experiment were taken by Mr. Henry Hibbert, Secretary to the Ashton-under-Lyne Waterworks Company, in expectation of his being sworn and cross-examined as to their accuracy before a Committee of the House of Commons in a matter involving the supply of the town of Manchester with water, great dependence may be placed on the correctness of the statements. Indeed, I am so satisfied of the accuracy of the observations and calculations made, that I doubt much if you will have a return from any other place more deserving of being relied upon.

The actual quantity daily supplied during the year 1847, appears to have been nearly 39 gallons per house per diem. The town, it may be observed, is one in good condition, where the wages of the working classes are high, and there are not, on the average, more than one family of five-and-a-half persons in each house.

Mr. Coulthart further states,—

In answer to your inquiry, "Whether, from further experience at Ashton-under-Lyne since writing my Report to the Health of

Towns Commissioners, I would modify the information therein afforded," I would simply say that additional experience has only more deeply confirmed the opinions which I then had as to the importance and economy of a continuous distribution of water for domestic purposes, by which tanks, ball-taps, and turncocks' wages are wholly saved, without anything existing in the unlimited-supply system to counterbalance these expenses, except, perhaps, that of laying down larger main-pipes. Indeed, daily experience is establishing in this part of England, and the annexed table corroborates the affirmative of the proposition, that a constant and unlimited supply is by far the cheapest method of supplying a given number of dwelling-houses with water; and that the system is not practically attended with that wasteful consumption of the precious fluid which the term 'unlimited' would seem to imply. When I wrote, in 1843, my Report on the Sanitary Condition of Ashton-under-Lyne, I calculated that an unlimited supply of water involved a daily distribution after the rate of 55 gallons per house, or 10 gallons per head of the population supplied; but subsequent experience has satisfied me that that was an over-estimate of what the public voluntarily use, and that 40 gallons per house, or 7 gallons per head per day, is amply sufficient, on the average, to meet all requirements of a domestic nature.

Having been informed by Mr. Rawlinson, one of our engineering inspectors, that at Wolverhampton a change had been made at his suggestion when reporting upon that town, from the intermittent to the constant system of supply, we directed queries to be sent to ascertain the results from the resident engineer, Mr. Marten. It appears that one immediate effect of the change was a reduction of 22 per cent. of the quantity previously consumed. The gross consumption, which was still 105 gallons per house, or building, seemed to be excessively large, as compared with the supply for other urban populations; but it appeared that, in that town, the proportion of manufacturers and great consumers is unusually large, and the intermittent system had limited the house supply, as explained in the evidence, thereby giving an unfair and extreme average. Mr. Marten states,—

From various observations I have been enabled to make, and the accurate accounts kept at Wolverhampton of the water delivered, I estimate the gross consumption of 128 gallons per house per diem may be divided into the following items:—

	Gallons.
To street-watering and town purposes . .	20
To trades and large consumers . . .	42
To washing out service-pipes and waste . .	31
To domestic supply	35
Total . .	128

He gives the following account of the change of system:—

Has there been recently any change in the mode of water supply?—Yes. The intermittent system continued in force about two years from the time of opening the works early in 1847, but the Company found the encouragement they met with under this system so extremely limited, and the objections raised against it so numerous, that they at length determined to abandon it; and early last year they introduced the method of constant supply. The change has met with decided success; and to show the unpopularity of the intermittent system of supply, although the houses within the district commanded by these works number upward of 7,000, yet, during the period the Company endeavoured to urge its adoption, they did not obtain more than 600 customers, or an average of 26 per month. On the adoption of the constant supply, however, an immediate increase took place, so that, in the 10 months during which it has been in operation, our customers have increased from 600 to more than 1,400, or at the average rate of 80 per month. I should observe, that although the system of constant supply was introduced early in 1849, yet, being tried as an experiment only, it was not officially announced until the 1st of January this year. Notwithstanding this disadvantage, however, the ratio of increase under this system has been 200 per cent. greater than under the old plan. The above facts may be taken as a fair test of its superior adaptation to the domestic wants of the public. The non-success of the intermittent system is not attributable to any want of canvassing, as every house in the district was visited during the time it continued in force, and great exertions were made to obtain customers. This increase has been continued up to this date, May 4th, and we are now adding to our number of customers at the rate of 50 each week.

Will you state some of the particular facts with regard to the intermittent supply which came under your notice, and which led you to adopt the constant system?—We found that people felt little inclined to go to the expense and inconvenience of erecting tanks in which the water was to stagnate during the greater part of the day, when, with a little extra exertion, they could always draw a constant supply fresh from the pumps. In many places, in the more densely populated parts of the town, there was no room on the premises for the erection of a tank, and when, in considera-

tion of these circumstances, the Company did not enforce the rules in this respect, it was found to be a great inconvenience to wait the particular times and seasons when the water might be turned on. In this case also the necessity of making use of the various domestic vessels (which could ill be spared) to hold the day's supply was felt and complained of as a hardship. The intermittent system also gave great dissatisfaction in those districts which did not receive their supply until the afternoon; these complained that they did not obtain the same advantage as their more fortunate neighbours, who received their supply in the morning. These instances illustrate the principal classes of objections raised against the intermittent system, and all of which more or less retarded its progress, and at last led to its abandonment.

Another inconvenience attaching to the intermittent system of supply, arises from the water during the greater part of each day lying stagnant in all the sub-mains or service-pipes; this is a matter of material importance in all water which does not readily precipitate a protective coating on the inner surface of the pipes, as, upon being confined a short period, it acquires a disagreeable taste, and becomes highly discoloured by the absorption of a quantity of oxide of iron; this is especially the case in sandstone water, and is a cause of much dissatisfaction, and requires, under the intermittent system, that the services should be washed out every day before the supply is given to the houses. This, of course, occasioned a great and useless waste.

Has it not been argued that this stagnation of the water in the pipes under the intermittent system is an advantage rather than otherwise?—Yes; it has been stated that 'the pipes then become additional settling reservoirs.' (See answer to question 4515 in Evidence before Health of Towns Commissioners, 1st Report.) Setting aside the fact that water so impure is actually so supplied as to require additional settlement, stagnation in the pipe will still be of no avail, as, if the pipes *are not* washed out previously to each supply, the whole of the sediment must be again stirred up by the incoming water, and driven into the tanks of the houses to be supplied. If, however, the pipes *are* washed out, the whole advantage of the settlement is likewise lost, as the fresh water from the mains in driving out the sediment will likewise drive out the clear water with it, and its place and the consumers' tank will be supplied with water in which the process of settlement has still to be completed. No advantage, therefore, can possibly be derived from the intermittent system on this ground, even in those waters where a temporary stagnation may not be a material evil. At Wolverhampton I found this a great disadvantage.

It was alleged by Mr. Wicksteed, the engineer to the East London Water-works, in his evidence given before the Commissioners of Inquiry into the means of

improving the Health of Towns, that the constant system of supply would require larger sets of pipes; for mains 71 inches instead of 20, and for side streets consisting of 100 houses each, pipes of 5 inches diameter instead of 3 or 4 inches. Now, it appears from actual practice questionable, whether a less instead of a larger trunk main would not be eligible as well as practicable. The experience of Mr. Marten, who had served for four years under Mr. Wicksteed himself, is in favour of an opposite practice to Mr. Wicksteed's. He was asked—

What alteration did you find necessary in the distributory department?—I find that very little alteration is necessary. The leading main laid down for giving the intermittent supply will be amply sufficient for giving the constant supply. The capacity of the submains and services will also be ample; these latter were all calculated for delivering the whole of the day's supply in the very small period of four hours, and there can, therefore, be no doubt but that they will be sufficient to deliver the less quantity required by the constant supply, especially when its delivery is spread over the whole day. The only material alteration I propose making in this department is to connect as many of the present dead ends of the pipes as possible, so as to keep up a free circulation. The advantages of this alteration will be more readily seen by considering the plan at present adopted in laying down water-pipes for the supply of a town. The line of the principal main having been marked out, the submains and services are branched out from it in various directions like the boughs of a tree from the main trunk. The consequence of this arrangement, which is a necessary evil under the intermittent system is, that a great many dead ends are formed, in each of which there is constantly a quantity of water stagnating, which soon becomes unfit for use, and must be washed out at a great waste of water.

Then you are of opinion that, with a free circulation, less oxidation goes on?—Yes; oxidation appears to take place in proportion to the length of time the water lies stagnant against the sides of the pipes; but by the proposed arrangement, the whole of the pipes being connected together wherever possible, so as to form a great network, a free circulation is kept up, the water always tending in all the pipes to the point of greatest draught. Thus, also, a *uniform quality* of water is maintained throughout the whole town, and the pipes, being fed at both ends, may be made proportionably smaller.

You think, therefore, that it is very important to have the cir-

culation active?—Yes. It presents many advantages, and in those cases in which I have applied this method it has answered admirably; and it gives me pleasure to observe, that the idea is taken from the perfect system of pipe-laying presented for giving a constant supply of fresh blood to the human frame.

In respect to the distributory apparatus at Preston, Mr. Quick was asked—

What is the smallest size main-pipe you know to have been used for the service of mains?—The smallest lead pipe for the service of a number of houses was a 1-inch pipe; it was the entire side of a long street of some 35 or 40 houses.

Under what head of pressure?—I only know that in the middle of the day we went to the last house. We examined and asked the person whether the water was on, and we were told it was never off. That was a house at the highest end of the street, and the flow was very free from a half-inch pipe.

Mr. Marten was questioned on the same topic.

What is the smallest sized pipe you use?—I have not been in the habit of using anything smaller than ½-inch, although I know such to have been the case at other works. I find a ¾-inch branch main more than ample to supply courts containing 13 houses.

How many do you think you have supplied from a ¾-inch main?—I do not remember an instance of more than 13 having been supplied from a single ¾-inch pipe, but I should not hesitate to supply 20 from the same pipe

Under the old system of supply, what sized pipe should you put down for the service of courts like this you have mentioned? —I cannot say what would have been the requisite size in this case, as under the intermittent system many parties left their taps running the whole time the supply was on, so that, to give all a due supply, the pipe would have been required of considerable dimensions. Under these circumstances it is the practice to lay down a 1½-inch or 2-inch pipe for the intermittent supply.

The same witness speaks of the effect of the change of system upon the purity of the supplies.

Have you had opportunities of observing the liability of the water to pollution from exposure to soot and dirt?—Yes. Where the tanks are situated within the house, the water soon loses its freshness and acquires a slimy character, and when exposed outside it rapidly accumulates on its surface a coating of the impurities invariably carried in the atmosphere of towns. In some waters exposed in this manner, fermentation quickly appears to take place, succeeded by an unwholesome vegetation, and lastly, the development of animal life. Filtration may clear this water,

but cannot restore it to its original state. In the summer time, and during warm damp weather, water exposed in butts becomes rapidly foul, and this takes place quicker in old than new tanks. I know an instance in which a butt supplied on the intermittent plan, although washed out three times a week, yet could not be kept clean; at the end of the second day a green scum had risen to the surface of the water, and there were a quantity of little red worms, and I was informed that several other tanks were worse than this. This occurred in the neighbourhood of London. At Wolverhampton, I have observed a thick yellow scum like floating sponge given off by the water when retained in tanks, and the water has acquired an unpleasant taste. In some situations water is rendered still more unhealthy by its power of absorbing noxious gases, so that people not only live and breathe in a poisonous atmosphere, but are also required to drink it condensed in the water.

Since the change of system have these complaints ceased?—Yes.

In the evidence given before the Health of Towns Commission, Mr. Quick fully admitted the effect of the retention of water in butts and cisterns in deteriorating the qualities of the supplies. In one communication from the New River Company to the City Court of Sewers, they are thus adverted to, as a main cause of complaints:—

It may be proper to add, that the quality of the water supplied by the Company seldom forms a subject of complaint. When it has occurred, some local defect in the pipe or cistern has generally been the cause.

We shall have further occasion to notice the evidence as to defects in the existing distributory apparatus, which augment the expense and deteriorate the quality of the water supplied; and we now beg leave to submit to particular attention one example of the introduction of a constant supply into the houses of the poorer classes, though that supply was derived from an intermediate and entirely unnecessary reservoir. On this point Mr. Quick was examined—

Has there been an instance of constant supply put on in London for tenements occupied by the poorer classes?—Yes, on a small scale, in Rose-court, Dockhead; and a small part of Jacob's Island, Bermondsey. The agent to Rose-court applied to the Company to ascertain the best means of improving the supply to his tenements, and at the same time get rid of the nuisance of a common tap, which

was running for two or three hours every day, and causing perpetual quarrels between his tenants and the people from Jacob's Island, who had not any supply from the Company. It was recommended to take away the common tap and erect a tank in some central situation, and lay an inch lead pipe with a half-inch branch to each house. This has been done, and the result has been a marked improvement in the people; as they now pay their rents regularly, being fearful that they would not find the same accommodation if they were to go to other houses; and the agent informed me that he was so well satisfied with the arrangements, that he would have the whole of the houses under his care laid on in the same way. The Company have also been gainers, as they save at least 200 or 300 gallons of water daily. The other supply is to 10 houses on a part of Jacob's Island, from a tank and an inch lead pipe with a half-inch branch leading into each house; the same result as regards the tenants has taken place in this case.

And you advise then, as the preventive for this disorder, that a constant supply should be laid on from one general reservoir or tank to small houses?—I believe that would be the most efficient way of affording a constant supply to large blocks of small houses, and it could be arranged very economically by persons availing themselves of the use of the Company's pipes beyond the branch leading into the tank as a feeder to the house services. It would also be a great protection to the high service of the district, as all the water must ascend to the height of the tank before it could be drawn off; and if the Company's pipes could not be used to conduct the water, a small service of one inch or more in diameter, leading from the tank with half-inch branches to the houses, could be laid in the most convenient situation, and would be the least expensive mode of giving a supply to houses that are not at present laid on.

Will you state the result of the experiment as to the comfort of the people?—The difference is very great; the agent to the estate informs me that quarrelling has scarcely been known among his tenants since the alteration, that the tenants never refuse to pay him the rent, and that he could obtain 3*d*. or 6*d*. per week more for each house if any of them became empty; and if he had 100 houses in the neighbourhood, with water laid on in the same way, he could find tenants for them at increased rents.

And the great waste must have saturated the ground and caused much dampness in the neighbourhood?—Yes, and the paving-stones were often washed up and the inside of the houses made very damp. The tank holds about 210 gallons, and provides an ample supply for 10 small houses, at about 20 gallons per diem for each house. The tank is filled every day.

With an average population then that is enough?—On an average

it is as much as is consumed in houses of that class—four-roomed houses.

From this case you may assume that the benefit might be extended to a larger class of houses?—Yes, to all, not only with advantage to the people themselves, but the Company also.

Further evidence received on this topic adds little to the illustration of the general condition of the distributory apparatus in the metropolis, though it brings out in stronger relief the state of knowledge and personal interests under which the existing system is maintained.

In other instances where it was confidently stated to us by engineers and managers of water-works that the consumption of water under the constant system of supply was much higher than those above stated, or nearly the same as on the intermittent method of delivery, we expressed a confident belief from knowledge and reasoning on the habits of the population that although the quantity stated might be, and doubtless was, delivered from the water-works, it could not be actually consumed, and there must either be a greater proportion of large consumers than usual, or that there must be waste from defective distributary apparatus.

For example, finding that with respect to the new soft water supply of Paisley and Glasgow, it was confidently stated that the consumption under the constant system of supply was about 25 gallons per head on the population, we conceived that if the fact were so, a more rapid and extensive change must have been wrought on the habits of the population than we had been able to hope for, or that there must be some waste from defective apparatus, and we therefore requested Dr. Sutherland to visit Glasgow and Paisley and examine into the fact, as well as the general sanitary results which had followed the introduction of soft water. He did so, and found that an unusually large proportion of the deliveries were by the wasteful practice of stand-pipes. Thus, in Glasgow, north of the Clyde, which is supplied with water by the Glasgow Waterworks Company, it was stated that there were about 32,000 families, or 160,000 inhabitants who drew their water supply from 1,800 stand-pipes, with taps ¾ inch

in diameter. It was also stated, that although six men were constantly employed in attending to these stand-pipes, it was found impossible to prevent waste from them, and that it was no unfrequent thing for the people to insert a nail to keep the tap open, and the water was sometimes allowed to run for days together before the waste was discovered It was estimated that about 33,000 families or 165,000 people were supplied within their own houses, or by water-taps placed in common staircases. These last are very numerous, and are used by all the families in the flat where the tap is situated. In that part of Glasgow south of the Clyde supplied by the Gorbals Gravitation Water Company, it was stated, that out of a population of 70,000, about 14,500 were supplied from stand-pipes, and that the remainder had water-pipes within their houses, or on landings in common stairs.

At Paisley it was found that out of 5,938 families supplied by the Water Company, and comprehending a population of about 30,000, no fewer than 4,738 families, or about 24,000 persons, derived their supply from stand-pipes.

Dr. Sutherland states that, with very few exceptions, the stand-pipes and common taps appeared to be in a defective condition, and leaked to a greater or less extent; and in some instances, the amount of escape evidently far exceeded the whole quantity consumed by the neighbouring population.

While this continuous waste was going on, he found an extraordinary discrepancy between the actual quantity of water consumed and the nominal supply thrown into the mains. This circumstance appeared to arise chiefly from the fact, that the parties using the water had to carry the whole of it from a greater or less distance, and up flights of stairs to their dwellings. The labour in obtaining the supply thus placing a direct restriction upon the quantity used. The extent of this and the evils of the whole system may be judged of from the following examples selected as affording fair average specimens of the actual consumption in houses of different rents, inhabited by the working-classes and obtaining water from stand-pipes:—

Number of Houses.	Number of Inmates.	Gallons of Water used per House per Diem.	Number of Houses.	Number of Inmates.	Gallons of Water used per House per Diem.
1	4	4	13	12	7
2	5	4	14	3	2
3	7	5½	15	7	6
4	2	4½	16	4	3
5	3	4	17	3	1½
6	2	3	18	5	4½
7	3	2½	19	6	3
8	7	6	20	5	2
9	4	4	21	2	2½
10	3	2¼	22	7	5
11	3	4	23	8	7½
12	3	2	24	6	3¾

The Totals of this Table stand as follows:—

Number of Houses.	Number of Inmates.	Total Gallons of Water used per Diem.	Gallons of Water used per Head of Population per Diem.
24	114	93½	0·82

In that portion of Glasgow, south of the Clyde the results of a similar inquiry were as follow, but in this instance the table contains a few cases in which the supply was derived from water-taps on stairs.

Number of Houses.	Number of Inmates.	Gallons of Water per House per Diem.	Number of Houses.	Number of Inmates.	Gallons of Water per House per Diem.
1	3	4	11	7	4½
2	6	4½	12	3	4½
3	7	6	13	3	2
4	6	6	14	5	4½
5	3	4½	15	4	6
6	5	6	16	4	12
7	5	6	17	4	5
8	5	8	18	10	6
9	3	6	19	4	8
10	3	3	20	7	4½

The Totals are as follows:—

Number of Houses.	Number of Inmates.	Total Gallons of Water per Day.	Gallons per Head per Day.
20	97	111	1·14

The results at Paisley were of a similar character.

Number of Houses.	Number of Inmates.	Gallons of Water per House per Diem.	Number of Houses.	Number of Inmates.	Gallons of Water per House per Diem.
1	3	6½	7	4	4½
2	4	6½	8	2	2
3	4	7	9	8	11
4	6	7½	10	4	3
5	4	8½	11	3	4
6	4	9	12	8	6½

The Totals are as follows:—

Number of Houses.	Number of Inmates.	Total Gallons of Water per Day.	Total Gallons per Head per Day.
12	58	76	1·4

It will be perceived that the per centage of water used in Paisley is somewhat greater than in Glasgow, which may be partly attributed to the fact that the houses are by no means so lofty, and that the labour of carriage is consequently less.

In each of these three instances we have then the following circumstances—1st, A constant supply of water to the extent of about 25 gallons per head per day of the population. 2nd, The actual quantity used for domestic purposes by a very large proportion of the people under 1½ gallons per head; and 3rd, An enormous waste of water.

These examples afford another illustration of the evils of separating works which are necessarily connected with each other. The officers who had charge only of the mains knew little or nothing of how much of the supply was run to waste, and what amount actually went for consumption.

The town of Stirling has recently obtained a constant water supply, which is furnished to a considerable portion of the inhabitants by stand-pipes. In this instance the distributary apparatus appears to be in a better condition than in the other towns, but nevertheless there is a considerable waste from leakage. The quantity sent into the mains is estimated at 13 gallons per head per diem, and yet Dr. Sutherland found on making

a household inquiry, that the quantity actually drawn from the stand-pipes for domestic use, did not for all purposes, exceed two gallons per head per diem. Where the water was carried into the houses, and there were proper sinks for the removal of the soil-water, there was an increase of the consumption of the water, and the houses themselves were in a better state of cleanliness. It was impracticable, however, to obtain, with similar exactitude, the real quantity consumed; but even in middle class houses, where the clothes were washed upon the premises, it did not appear that the daily consumption exceeded 12 or 13 gallons per diem.

Upon the consideration of the state of things brought to light up to this point by our investigation, the question will naturally arise how, with such extraordinary waste, and consequently loss of pumping power and expense, the Companies themselves do not out of mere regard to their own interests adopt the constant system of supply?

The answer is, that it would be wholly subversive of their present system of charges, and their immediate commercial interests. If the constant system of supply were adopted, it would be impracticable to have numerous variations of the heights or rates of delivery, or of charges for delivery at high or low pressure. Mr. Wicksteed, the engineer to the East London Water Company, estimates the expense of pumping by the Cornish engine in London at 1*s*. for raising 80,000 gallons 100 feet; or, in other words, 9*d*. per house for lifting a year's average supply 100 feet.* But his Company's charge for raising the water more than 14 ft. high above the ground floor of a lower class house would be 14*s*., or 18 times the acknowledged cost to the Company; and there would be no pretext for maintaining such rates of charge, under the system of constant supply at high pressure. The following returns show the charges for high service by the several Companies.

---

* *Vide* also Appendix, Mr. Hocking's evidence. This cost, however, is exclusive of interest on capital, for the proportion of which and other expenses in Nottingham, *vide* Mr. Hawksley's table in the Health of Towns Report.

ANALYSIS of REPLIES to QUERIES addressed to the several Water Companies respecting Supplies of Water at High Pressure.

NAME OF COMPANY.	Highest Service above high-water mark.	Lowest Service from high-water mark.	Height at which High Service commences.	Extra Charges for High Service.				Gross Charge for High Service annually.
								£. s. d.
New River Waterworks	430 feet.	5 feet above.	6 feet 6 inches above pavement.	13 feet, 25 per cent.	50 feet, 50 per cent.	Above 50, 75 per cent.	Above rates.	11,442 0 0
East London Water-works	120 feet.	3 feet below Trinity high-water mark.	10 feet above pavement.	From 10 to 14 feet, 25 per cent. on rate.	From 14 feet upwards 50 per cent. on rate.	. .	. .	747 17 0
Southwark and Vauxhall Water-works . .	150 feet.	Below high-water mark.	. .	No fixed separate charge.				883 0 0
West Middlesex Water-works . . .	207 ft. 6 in.	About 20 feet above.	6 feet 6 inches above pavement.	From 25 to 50 per cent. on the low service; maximum £3 per annum.				12,000 0 0
Lambeth Water-works	350 feet.	4 to 5 feet below.	10 feet above pavement.	50 per cent. on the lowest rates for low service.				945 0 0
Chelsea Water-works	157 feet.	4 feet above.	10 feet above pavement.	No fixed separate charge.				2,600 0 0
Grand Junction Water-works	150 feet.	12 feet above.	6 feet above pavement.	Entrance, 26·1 per cent.	1st floor 43·4 per cent.	2nd floor 59·3 per cent.	3rd floor 76·2 per cent.	10,763 17 5
Kent Water-works	220 feet.	High-water mark.	No return . .	No fixed separate charge.				No return.
Hampstead Water-works	215 feet.	60 feet above.	7 feet above pavement.	Above 7 feet, and not exceeding 14 feet, from 25 to 40 per cent.		Exceeding 14 feet, from 30 to 50 per cent.		441 5 6

As examples of the charges made for high service, it may be stated from the returns, that a 12 roomed house, for the low service of which the average charge of the Grand Junction Company would be 2*l*. 10*s*. per annum, the rate would be 2*l*. 5*s*. extra, or 4*l*. 15*s*. per annum for the high service. For the same house the average charge of the Lambeth Company would be for low service, 2*l*. 10*s*. 6*d*., and for high service 3*l*. 11*s*. 6*d*., with an extra charge for a water-closet on the basement and first floors of 1*l*. 2*s*. 6*d*., making a total of 4*l*. 14*s*.

Under the pressure of demands for the sanitary improvement of the worst-conditioned tenements, more especially in water supply, a proposal has been made by the Southwark and Vauxhall Company to give a constant supply to them, by means of an intermediate reservoir on the plan described by Mr. Quick, the effects of which, as partially tried, have been already stated. In this, and perhaps in any form, the system of constant supply would be an improvement; but the first objections to the intermediate reservoir, are that it would occasion the pollution of the water by exposure to soot, and town air, the elevation of temperature, and the absence of the proper conditions for delivery. The next objection is the unnecessary expense of an intermediate reservoir, or large tank. The tank, or intermediate reservoir, as shown in one example, adds one-fourth to the expense of the apparatus for supplying houses of the poorest class. This, however, is a saving of three-fourths in the expense of water-butts and tanks to separate houses, and of much more than three-fourths in disorders and inconveniences.

The effect of this arrangement, which provides against immediate objections, as respects the worst-conditioned class of tenements, would be to keep up the intermittent system of supply on its present footing for the middle and higher classes of houses, and the charges for high service in the case of all.

Assuming the case between owners or occupiers of the middle and higher classes and the water Companies, to be one between sellers and purchasers who had

no claims to intervention for the reduction of existing charges; setting aside any claims of those classes, on sanitary grounds, to a share in improvements of the qualities of their supplies, there are the following objections, which appear to us to be of importance to the public, against a retention of the intermittent system of supply, even if private individuals were to claim its continuance:—

First, that neither private traders nor private consumers, if they may be so designated, can have any just claim to carry on a method of supply, one consequence of which is a waste of water greater than the supply itself, which causes a flooding of houses, by which others besides themselves are subjected to the injurious effects of damp, and to charges for the removal of the excess of waste water.

In the particular district for which the arrangement is first proposed, the south side of the river, this objection is strongly exemplified; a large proportion of first and middle-class houses, from which the Companies' trading profits for high service would probably be greatest, have the more elevated positions. From them, the waste, which exceeds the rainfall, flows down and floods the lower districts. Every cubic foot of water, which the Companies, by the intermittent system throw upon the district in waste, must be continuously pumped out, at the public expense from the sewers, or worse evils, which already exist there, must remain; the waste water being ponded up in large reservoir sewers during the whole of the high tides, until it can be discharged at low water. The flow being arrested during the ponding up of the sewer water, the matter in suspension is deposited, and much of this deposit becomes indurated, and can only be removed by mechanical means. These deposits, within this district, at present cause an annual expense to the rate-payers about equal to the probable yearly expense of a proper system of main drainage. While this waste more than doubles the rain-fall, it also more than doubles the evils of the present system of intermittent drainage without pumping, the chief of which are thus cor-

rectly enumerated by Mr. Grant, engineer of the Surrey district:—

What, from your own experience and observation in this district, do you consider the effect of ponding up the sewage by the intermittent system of drainage?—1. That it requires that storage room should be provided not only for the ordinary amount of sewage collected during the six or seven hours that the outlets are closed, but for the extraordinary falls of rain which sometimes occur during high water. 2. This storage room is obtained in the most expensive manner by making prolonged reservoirs, thereby making the most extravagant use of materials. 3. That the sewage, instead of being got rid of from every house and street as rapidly as it is generated, is retained to the detriment of health and comfort. 4. That during this detention the grosser particles are deposited, and accumulate at such a rate as to require constant manual labour for the expulsion of the deposit. 5. That the discharge into the river can take place only at the most objectionable time, namely, at or near low water, when the return of the tide carries the sewage up the river instead of carrying it away. 6. That the limited fall is made still less by the necessarily large size of the sewers, and the great length to which such main lines must extend. 7. That the sewers require expensive adjuncts in the shape of side-entrances, flushing and ventilating gratings, the cost of which, added to the constant expense of cleansing, makes it a very expensive mode of drainage.

In illustration of the connexion of defective arrangements for water-supply, with defective systems of sewerage, it may be mentioned that the lower districts of Westminster are subject to this evil of intermittent drainage in an aggravated degree. The pollution of the air of one of the law courts in Westminster, recently ascribed by some learned judges to bad ventilation, was really due to defective drainage arrangements, and its aggravated state, in periods when there was no rainfall, must be attributed to the excess of flood water from the intermittent supply, retained during the periods of high tide. The gulley-shoots had been trapped, to protect the passengers in the street from the effluvia arising from the deposit in the house-drains, and main sewers, occasioned by the intermittent system of drainage. But by trapping, these gases were only kept in greater intensity in the sewers, which were filled with polluted air at each discharge of waste water, when the flood-gates were closed. The augmented flood of pipe or

waste water coming into the partially closed reservoir, and rising, drives the air out of the sewers in greater quantities, through badly-trapped drains, through rat-holes, through the smallest crevices, and through permeable walls, into private houses and public edifices. The connexion of the above-mentioned court through a drain with a sewer in that condition was clearly traced. The operation of mechanical ventilation above quickened the ingress of polluted air from beneath.

Secondly. The excess of waste water consequent on an intermittent supply, must obstruct the public arrangements necessary for the removal and application of sewer water as manure, and for preventing the pollution of the river. The excessive waste more than doubles the dilution, and augments the bulk of transport inconveniently. Mr. Mylne, the engineer of the New River Company, when acting as engineer to the Sewage Manure Company, manifested great anxiety, in taking for them the sewer water from the lower districts of Westminster, to avoid the effects of extreme dilution of the sewer matter from the waste-pipe water, which he was confidently of opinion would render sewer matter of little value for the object in view. The immense mass of the refuse of the metropolis, and its peculiar position, may render necessary the transport of sewer water to considerable distances, and all unnecessary augmentation of bulk will, as to this point, be a proportionate impediment to public work.

Thirdly. The retention by water Companies of the intermittent system of supply for the higher and middle classes of houses, enhances the expense to the public, and the danger to life and property; keeps up excessive insurance risks; and is mainly chargeable with the destruction arising from the present imperfection of the arrangements for extinguishing fires.

The observations already made on the peculiar disadvantages of a closely-packed town community, as compared with a rural population, in respect to the *quality* of their water supply, are to some extent applicable to the condition of the town population as

respects the distribution of that supply. If the water is not brought into their habitations, the town population is put to far greater inconveniences in fetching it than the rural population, even where stand-pipes or fountains are provided. In densely-packed districts of the town, supplies of water are required at the same time for large numbers, and sometimes for crowds. Hence the conflicts for priority of supply, and the violences of the stronger on the weaker claimants—circumstances often rendering the distribution a subject for police regulation.

It is commonly considered that a sufficient and even liberal arrangement is made for the poorer classes if supplies of water be brought within their reach in public fountains or in stand-pipes, placed in their streets and courts, at which they are allowed to help themselves gratis. The notion, however, that such supplies can be gratis, is wholly erroneous. As compared with what may be accomplished by the supply of the water under natural or artificial pressure they are highly expensive, and to the poorest classes, who can least afford waste of that which is their only property, namely, their labour, the arrangements in question are the most oppressively costly,—so costly as to act as prohibitions of the full and free use of such a quantity of the natural element as is requisite for health and comfort.

To illustrate this, we might take the case of a family, living at one end of a court, having to fetch their water from a stand-pipe at the other end of the court. The more frequent case, however, would be that of families living in upper stories of the old and higher houses in towns, and having to carry up water into their own rooms. We will suppose the case of a family living on a third or fourth floor, and actually consuming 50 gallons per diem.

This would be upwards of 20 pailsful per diem, or 140 pails per week to be fetched from the stand-pipe below. The weight of water alone to be carried per diem would be 500 lbs., or, per week, 3,500 lbs.; add one-fourth to this, as the weight of the pitcher or pail, and the actual weight carried is 4,375 lbs. To fetch the

water, and carry such a weight, would probably require the amount of two days' labour in the week.

In towns it generally occurs that for persons capable of performing such labour there is other labour to be performed, yielding wages however low. Suppose the labour to be performed by the labourer's wife, and that she could otherwise gain only 6*d.* per diem, the expense of fetching and carrying will be 1*s.*

But few of the tenements occupied by the labouring classes, or indeed of the upper rooms of houses occupied by the higher or middle class, have any waste or "return pipes," and the whole of this waste water would have to be carried down again, which would double the amount of labour.

The consequence of this excess of labour is, that though the water may be brought to the very door, or into the yard, there to be distributed gratis, the labour, *i. e.*, the expense, acts as a restriction on the use of the commodity to the smallest quantity that can suffice. The female may be seen with a child in one arm, which she cannot leave alone, painfully carrying up-stairs a pail or a large jug of water. This, in consequence of the severity, or extreme inconvenience of the labour, she makes suffice for the day. At night the husband comes home, tired from his work, and dispenses with the means of an evening's, and even a morning's ablution, rather than be at the trouble of fetching the water; and bad weather, rain, or snow, frequently second the disinclination. Instead of the labour of the poor spent in these and the like exertions costing them nothing, and being the easiest spared, as the common theory of the provision by gratis fountains and stand-pipes assumes, their labour, not only in consideration of the exhaustion by other and more profitable work, but of the casualties from sickness, helplessness, and decrepitude, requires to be most carefully economised by arrangements on a larger scale. When it is known that (in the absence of cheaper means of elevation by natural pressure) 30,000 or 40,000 pailsful of water may be lifted upwards of 50 feet high for 1*s.*, by the application of steam power, it will be per-

ceived that it amounts to pecuniary waste on the largest scale, to continue to impose such an amount of labour on 30,000 or 40,000 females, apart from any consideration of the cruel inconveniences which such a labour must impose.

Public men, and even engineers, regard large aqueducts with copious and visible discharges of water by fountains as conclusive evidence of the fulness and completeness of supplies of water. But the finest river may be at the very doors of a large proportion of the population of a city—as is the case, indeed, with the Thames and its tributaries—and yet the supplies to the inhabitants, and especially to the residents of upper tenements, may, from the want of proper distributory apparatus, be as restricted as if such river were at a distance. In all continental cities, where the supply to upper rooms is by hand labour, the actual consumption is extremely small. We believe that, in Paris, the domestic consumption does not exceed two gallons per head on the population, even in well-conditioned districts.

The waste of labour in lifting water supplies from a well by the machinery of a common pump, is similar to that above described. The expense of sinking and forming the well, of the pump itself, machinery, interest, care and repairs, usually is about four times the rate of contribution requisite for the large distributory apparatus, which is moved by an immense steam-engine of several hundred horse-power, one of the highest combinations of science and art.

Now, we are assured by our engineering inspectors, who have closely examined the subject, that it would be practicable to obtain contracts for the establishment, as well as maintenance of apparatus in good action and repair, during a term of years, for the collection and storage of water 26 miles off; for filtration, and conveyance of the 50 gallons or more that distance; for its delivery on the spot, and for lifting it up to the fourth story of any house or building at all times fresh and pure, at a rate of 1*d.* per week, and for the conveyance away of all waste or polluted water,

of another 1*d.* per week for any such highest floor, or at the rate of 2*d.* per week each for the whole house.

These prices, at which the work might be executed and maintained under well-considered contracts, render it a pecuniary extravagance for a woman employed in needlework, or the lowest-paid labour, to fetch water from the bottom to the top of a house, although when at the bottom she may obtain the water gratis.

On such grounds we are prepared to state, in answer to objections made to the introduction of the Public Health Act, on account of the distressed and depressed condition of the population, that it is because they are depressed, that it becomes the more important to have immediate recourse to the means of reducing domestic charges as well as local burthens, and for this purpose to apply the Act, which, under the new system of the distribution of charges over periods of time, requires no immediate outlay, and is in its immediate effects a direct source of large and lasting economies.

The system of gratuitous distribution, by intermittent, or even by constant supplies at stand-pipes or fountains, is open to the further objection, that whilst from the labour it imposes, it is expensive to the parties intended to be benefited, it subjects the rest of the inhabitants to additional expense in erecting and maintaining these places of supply.

That the convenient distribution of water governs the habits of households of the higher and middle classes, is shown by the fact, that when the delivery of the water is interrupted by any defect in the distributory apparatus, or by frost, and additional labour is interposed in the way of obtaining water, the house cleansings and washings are diminished in frequency, and every presumption is afforded that if it were at all times and in all weathers, requisite to send to a distance for water, the habits of household, and even personal cleanliness in such dwellings, would be deteriorated. The extension of conveniences for cleanliness and decency must precede the establishment of cleanly and decent habits among the labouring population. At the commencement of our investigations into the means of improving

their sanitary condition, it was conceived, that the extension of the conveniences must precede and form even the inclinations for their use; but the Inspectors who have made house-to-house visitations in the worst-conditioned districts, are unanimous in reporting the strong appreciation by their inhabitants of the benefits of the proposed works, and their hearty willingness to contribute rates, in return for such benefits.

From all the information we have received, in respect to the present habits of the population, and the probable extension of the use of water by the introduction of supplies of superior quality and improved distribution, we believe that it will be an ample estimate, comprehending, indeed, many new and unforeseen uses, if we provide for the daily supply to the whole population of an average equal to the actually ascertained consumption in houses of the higher class, namely, of about 75 gallons per diem per house. This would amount for the 288,000 houses within the Registrar-General's Metropolitan district to 21½, or say 22 millions of gallons per diem. Adding also the existing amount furnished to large consumers, the prevention of waste by whom would be equal to a probable extension of supply to those who do not now receive it, and the total daily volume would be 24¾ millions of gallons. Add to this, the gross demand for fires, street-watering and flushing, at the present rate of consumption, of one million and a quarter, and we have a total of 26 millions of gallons per diem, making for 288,000 houses little more than one-half the average quantity now delivered for the supply of 270,000 houses only.

It is not expressed in the prospectuses of any of the schemes now before Parliament, nor does it appear in any of the schemes which we have examined, that provision is made to meet the demands for a general abolition of cesspools, or for the new uses, which would be provided for in the estimate of a supply of 22 millions of gallons per diem; neither do any of these schemes estimate or provide for the systematic surface washing of foot-pavements in courts, alleys, and

streets, or the surface-cleansing of carriage pavements by hose and jet, which would require an increased provision, the extent of which we shall subsequently state. Nearly every scheme does, however, appear to contemplate the use of very large additional supplies, specifically for cleansing house-drains and flushing sewers: but it will be found on examination, that in contemplating the introduction and use of additional supplies for that particular purpose, they rely upon the continuance and extension of drainage-works wholly erroneous both in theory and practice.

Unless we keep in view the chief circumstances out of which wasteful works have arisen, and unless those circumstances, which consist mainly of defective administrative arrangements, are totally changed, the steady improvement requisite for the perfection of future works is hopeless.

The preceding evidence in relation to the effects produced on the sites of houses, by the discharge of waste water without adequate means for its constant removal, has displayed some of the chief consequences of a separation of essential parts of the same works.

One consequence of this which remains to be noticed is, that the common engineering plans, and the usual method of supply by water Companies, direct attention to one and the least expensive portion only of the apparatus for the supply of water, namely the large and public mains, whilst they divert attention from that which is really the largest and most important portion, the house service-pipes, the capillaries of any proper system. The chief effects of the separation of these two essential parts, are shown in the large waste, deranged action, and augmented expense already described. The interest of a water Company, as at present constituted, must be to confine their capital to visible or public stock, such as their reservoirs and street mains. Sometimes in the unnecessary sizes of these, and sometimes in their alleged cost, so much beyond the market price, our engineering inspectors find evidence of jobbing or gross mismanagement. But another consequence of

the separation of parts which should be connected, is the great unnecessary expense, incurred in one part, to effect a comparatively small immediate saving in the other. Thus the Companies, to save their own capital, carry single mains down the centres of streets. The effect of this, is to cause every private owner or occupier to carry the leaden service-pipe from back to front of his house, and thence to the main in the centre of the street. If, instead of one six-inch pipe in the centre of the street, water was distributed by two four-inch pipes, one laid down on each side of the street or under the foot pavement, the reduction of length in house service-pipes would not only cause a large reduction of the whole expense, but would render the apparatus more compact. Companies, moreover, by thus laying their mains in the centre of streets, render them subject to violent concussions from carriage traffic over the surface, and more frequent leakages, which increase the expense of repairs. To save earthwork, they also frequently lay their mains as near the surface as may be compatible with avoiding frost. In doing this they not only increase the effect of surface concussions, but they do what is a greater injury to the public, namely, raise the temperature of the water towards the higher temperature of the surface, instead of delivering it of the lower medium temperature of shallow spring water, which may be maintained by due depth and proper care in laying the distributory apparatus.

It will hereafter be shown, that under the improved arrangements, which are perfectly practicable with properly combined works, the whole expense of a distributory apparatus may be reduced to less than one-half the expense incurred under the present practice.

From the whole of the evidence, it is clear that the existing Companies supply an insufficient administrative machinery for improvement of the supply of water, separately considered; for that supply can only be improved by measures in detail, from which *immediate* profit is not to be expected, while their eventual profit cannot easily

be made clear to meetings of shareholders. This circumstance, which is prejudicial to the improvement of any water supply, is still more so to the required combination of water supply with drainage works, or to an improvement of the latter under any such connexion. The isolated position of many of the Companies, does indeed create an interest hostile to the proposed combination, as was shown by subscriptions entered into by some of them for the avowed purpose of raising up an opposition to a Public Health Act, which provided for the combination of local works under one and the same management. The like opposition is, we find, frequently raised by interested engineers, and the shareholders in provincial Water Companies to the application of the Public Health Act to certain towns where their works are situated, where the Company is not bankrupt from continued mismanagement, and where there are no preponderant hopes of gaining large compensations by a forced sale of their almost useless works.

In the examinations of the claims for compensation for local works which are required to be combined with new works for sanitary improvement it is common to find accounted as part of the capital invested, enormous charges for Parliamentary expenses in obtaining local Acts, and these expenses swollen by charges for the services of professional witnesses, whose practice sometimes appears by no means advantageously in the nature of the works supported by their testimony. The example of the allowance of separate works and the multiplication of capitals for the public service on the same field of supply, is attended by the evil of the increased numbers of professional witnesses engaged in the promotion of local separate works and in opposing their consolidation. The evidence of the same professional witness has been given before one Parliamentary Committee in favour of a constant supply, and before another against it—advocating in the latter an intermittent system. Another witness has, in different Committees during the same Session of Parliament, given evidence in favour of a supply obtained by pumping from the red sandstone, and even from limestone,

in preference to a collection from gathering grounds; and in another Committee he appears as a witness for a scheme of supply by gathering grounds as opposed to one for pumping; and opposed, not according to any essential or real variation in the necessities of the case, but according to the incident of the retainer.

We have had the decided testimony of a chemist as to the unfitness and insalubrity of the water of a particular stream; and afterwards, on a retainer from a trading Company, that same chemist has tendered an unqualified certificate to the fitness and salubrity of the water of that very stream, only taken some way further up, and of the same essential qualities. Another professional witness frankly stated to us as the reason for his intimate acquaintance with the subject of gas works that he had been engaged as a chemist to give evidence sometimes for them and at other times against them; that is, at one time to prove and at another time to disprove that they were nuisances. The real nature of this class of testimony is only more clearly displayed to persons who have some acquaintance with the subject by plausible selections of immaterial and non-essential incidents on which to justify diametrically opposite testimony in respect to works essentially the same.

We find, based upon such testimony, disorganized works, high charges and imperfect supplies, and the failures of Companies. With even an intimate acquaintance with the subject, it is difficult to avoid being misled by such witnesses; but local Boards, having no previous acquaintance whatsoever with them, and less interest and responsibility than the directors of Joint Stock Companies, are frequently entirely at their mercy.

In respect, indeed, to works for the distribution of water, though the elements of the science of hydraulics are fixed and certain, yet the experiments on which the applications of the science to this particular purpose are founded, have been made on a very limited scale, and on scanty observations. The practice at the commencement of these investigations was extremely loose and empirical.

This is evident from the widely varying arrangements of works under similar conditions. The economic, as well as engineering failures, in part owing to a separation of works, are displayed in the results of inquiries under the Health of Towns Commission, where out of 50 sets of water-works generally constructed by water Companies under local Acts, "in only six instances could the arrangements be deemed in any comprehensive sense good, while in 13, they appear to be indifferent, and in 32 so deficient as to be pronounced bad." These economic as well as engineering failures, we find generally result from the trading habit amongst persons who promote and then undertake such works of resolving all doubts on the side of expense. This is ascribable to this circumstance, that failure on the part of payers, whether shareholders under a private Act, or ratepayers under a corporate Act, is no failure to the professional and trading promoters of such works, who are commonly benefited, indirectly as well as directly, in proportion to excessive expenditure. Such, also, is the public inattention and ignorance in relation to this class of works, that those who find the means have no standard by which to judge of the extent of failures, which are therefore little heeded, and affect but little the professional reputation of engineers employed on such works. Consequently there are very feeble motives to attain to that complete knowledge which ensures exactitude, and which directly leads to a reduction of expense, and such knowledge put into practice would also frequently involve a reduction of emoluments from the particular work in hand.

The like state of empirical knowledge, supplying motives to cover ignorance, or resolve all doubts on the side of expense, has extensively prevailed in respect to drainage works. Here, however, the administrative defect is ascribable to want of special information, and to the effect of an erroneous presumption pointed out in the Sanitary Report, that the incidental attention of persons of good general capacity is sufficient for the origination of new works, to remedy the evils expe-

rienced. When we have to submit for consideration the administrative means for the execution of works for improved water supply and drainage of the metropolis, it will be requisite to adduce other facts in illustration of the unfitness of joint-stock trading Companies for the execution of such works, for reasons inseparable from their constitution and position.

III. We now come to the *third* head of our inquiry, viz., as to the mode of removing water after it has been used and discharged, especially in the case of the damp and low lying districts of the metropolis.

It has been already stated that among the schemes proposed for the supply of water to this metropolis, several contemplate the provision of a quantity for flushing drains and sewers, nearly equal to the volume supplied or proposed to be supplied for domestic consumption.

A determination of the question raised on this point, of the extent of additional supplies required, involves an examination of the evidence relating to the whole system of works for the removal of waste water.

At the commencement of this investigation no settled rules were found for the determination of the size and arrangements of waste or return pipes, or house-drains requisite for the removal of waste water from houses. Every district, and almost every street presented wide and expensive diversities of practice.

The state of knowledge and practice at the commencement of official inquiry is displayed in the following portions of examinations cited in the First Metropolitan Sanitary Report:—

Another surveyor of the Kent and Surrey District, Mr. Joseph Gwilt, the author of the "Encyclopædia of Architecture," was questioned on this topic, on which so important a part of the town drainage depends.

It appears that there were in the metropolis in the year 1841, 270,000 houses. Now, if each were to have at the least a 9-inch drain, as you and architects recommend, it appears that the area of the stream or river required to keep them full and flowing, would be a stream 1132 feet in width by 105 feet in depth?—Yes.

It is estimated that a supply of water for the whole of the metropolis, supposing each house to have a supply of 125 gallons per diem, or 25 gallons per head, would be given by a circular tunnel or aqueduct $12\frac{1}{2}$ feet diameter. There are in the Kent and Surrey Districts, 55,000 houses, and the supply there would be given by an aqueduct of proportionate size to your number of houses, say one-fourth. Such being estimated to be the size of conduits required to bring in water, it is presumed that the sectional areas of the drains and sewers would not be required of vastly greater size, supposing them to have as good a fall, to carry away the same water. Can you prove any addition of rain-water, or even of extraordinary storm water, requiring a system of drainage of a sectional area more than five times that of the Thames at Waterloo Bridge at high water, or nearly one thousand times the area of the aqueduct that would furnish the whole supply of water to the metropolis?—I apprehend, in providing drains for a house, you are to provide against accidents, therefore I should say it would be prudent always to have drains larger than are actually necessary, to guard against stoppages. A stoppage in a small drain stops up the whole orifice, a stoppage in a large one is partial. There may be most likely a means of its running off in some way or other.

It has been stated that the smaller the pipe is, generally, the less likely will deposit be to accumulate, the greater will be the force of water concentrated upon the resisting medium, and the less likely is the resistance of that medium to be effectual. What is your opinion upon that subject?—My opinion is this: I will take the case of a washer to a sink being open, and the cook throwing down anything that comes to hand; it comes against a 4-inch pipe, and blocks it completely up; but the end of a cabbage-stalk will pass into a 9-inch drain, and there it will lie and decompose.

Do not you know that sometimes servants or persons living in attics will throw out substances of all kinds into the gutters? Would not that equally be a reason for making the water-spouts of 9 inches, a diameter as large as chimneys, to carry off accidental substances so thrown in?—Perhaps it would be better in many cases, but we cannot remedy that.

This witness sets forth in the "Encyclopædia of Architecture" that "for a moderately sized country mansion," a drain with an area of 5 feet is necessary." This is a capacity sufficient, with a moderate fall of water, to discharge 2000 cubic feet of water per minute; and he justifies the use of this space as requisite, "not merely for the sake of carrying off the water, but that the conduit may be capable of being cleaned out at

intervals by the entrance of men without breaking the whole sewer to pieces."

These views in respect to the sizes of house-drains are indeed embodied in the Metropolitan Building Act, where it was provided that the minimum size of every house-drain or pipe for the discharge of waste water from a house should be 9 inches in diameter.

Many noblemen's houses and mansions have been sewered at great cost upon these erroneous principles, and the water-closets are, in consequence, a constant annoyance and expense. Single houses have around and within them drains five feet high, to take off, not the solid refuse, (cesspools have been made to retain this where it can act with the greatest effect for evil,) but only the liquid overflow, which, if running 24 hours each day, would not fill an inch pipe. Large sums of money are at present expended upon fruitless attempts to repair water closets, when the real evil exists in the cesspools and large drains within and under the houses out of which the refuse never passes. A river of water would scarcely cleanse them.

On the appointment of the consolidated Commission of Sewers for the Metropolis, the necessity of obtaining by trial works closer approximations to correctness on this matter was urged upon the attention of the Commissioners, and their consent was obtained to experiments on a limited scale for the purpose.

Assuming the maximum house supply of water to be 100 gallons per diem, trials were directed to determine in what time pipes of given sizes and inclinations would discharge that quantity.

Mr. Medworth, the officer who executed the directions, gives some of the results in his examination, from which it will be perceived, that a cylindrical drain of 3 inches diameter would discharge in three minutes the twenty-four hours' supply of water, and that a 4-inch pipe would discharge the day's supply in a minute and a half. His examination then proceeds:—

What quantity of water would be discharged through a 3-inch pipe on an inclination of 1 in 120?—It would discharge 100 gal-

lons in three minutes, the pipe being 50 feet in length, and not more than half-filled. This is with stone-ware pipe, manufactured at Lambeth. This applies to a pipe receiving water only at the inlet, the water not being higher than the head of the pipe.

What would be the rate of discharge, supposing the whole 100 gallons to pass through the drain from the back to the front of the house, say some 60 feet, and how soon would the water be clear of the premises?—All that could be swept away by 100 gallons would be discharged clear of the house at the rate I have already stated.

What would be the power of sweep?—Sufficient to remove any and even more than ordinary and usual semi-fluid deposit that is found in house-drains; that is, supposing the whole of the 100 gallons was to be discharged in the time stated.

What water was this?—Sewage-water, of the full consistency, and it was discharged so completely, that the pipe was perfectly clean.

At the same inclination what would a 4-inch pipe discharge with the same distances?—Twice the amount (that I found from experiment); or, in other words, 100 gallons would be discharged in half the time. This likewise applies to a pipe receiving water only at the inlet, and of not greater height than the head. In these cases the section of the stream is diminished to about half the area of the pipe.

Then a 4-inch pipe will discharge a 24 hours' supply of sewage-water a distance of 50 feet in a minute and a half?—Yes; taking the 24 hours' supply to be 100 gallons.

Did you not try the force of this discharge with sand? and, if so, with what proportions?—Yes, with sand in proportion of from 1-16th to 1-40th the volume of the water, and the sand which was held in suspension was entirely removed.

But the different construction of the pipe with respect to smooth ness will make full a fourth difference in the rate of velocity?—Yes; with the red-ware pipes formed by pressure, the accelerated velocity due to regularity of form and smoothness of surface was one-fourth.

Have you not found that exactitude in the make is more important than the glaze?—Yes, the exactness of form and ACCURACY of JOINT are very important, so that the pipes may run into each other and form a complete cylinder. As an instance of the importance of exactness of joint, I had a case happen at one of my houses within the last few days. The tenant complained of the stoppage of the drain from the closet, &c. Upon sending a man to make an examination, it was found that the trap contained several oyster-shells, and one had been discharging into the other, where it was arrested by an imperfectly formed joint.

Then you found on experiment that this exactness of form expedited the discharge full one-fourth?—Yes. As before stated

in the case of the red-ware pipe; but upon comparing the results with the Lambeth stone-ware, the difference was in favour of the latter.

Have you tried the effect of junctions on the main?—Yes.

Suppose two of these 4-inch pipes were joined, what would be the velocity gained by junction into a main?—At an inclination of 1 in 60 the increased discharge would be in some cases nearly double; that is, the single pipe will deliver 84 gallons per minute; the addition of another 4-inch pipe will increase the discharge to 162 gallons per minute. The discharge will vary, dependent upon the position of the junction on the main line; the further from the head or inlet the greater the discharge.

Before these experiments were made, were there not various hypothetical formulæ proposed for general use?—Yes.

What would these formulæ have given with a 3-inch pipe, and at an inclination of 1 in 100? and what was the result of your experiments with the 3-inch pipe?—The formulæ would give 7 cubic feet, the actual experiment gave $11\frac{1}{3}$ cubic feet: converting it into time, the discharge according to the formulæ, compared with the discharge found by actual practice, would be as 2 to 3.

Or, putting it into another form, if there were a given quantity of detritus or fæces to be removed, it would, according to the formula, require nearly double the quantity of water that was found absolutely requisite in practice?—The proportionate discharges were found to be as 2 to 3, therefore the power required would be in those ratios.

How would it be with a 4-inch pipe?—The formula would give about 14·7 cubic feet per minute, whereas practice gave 23 cubic feet per minute.

Take the case of a 6-inch pipe of the same inclination?—The result, according to Mr. Hawkesley's formula, would be $40\frac{1}{3}$ cubic feet per minute; from experiment it was found to be $63\frac{1}{2}$ cubic feet per minute.

Will you convert that into time, and consider the 6-inch pipe as a small branch sewer? Within what time would 100 gallons be discharged at the same inclination over 50 feet?—It would be discharged in 15 seconds.

That is to say, that the actual experiments prove how much less water can be made to suffice than these formulæ prescribe?—Precisely so.

Then with respect to mains and drainage over a flat surface, the result of course becomes of much more value as the difference proved by actual practice increases with the diminution of the inclination?—Certainly, to a very great extent. For example, the tables give only 14·2 cubic feet per minute as the discharge from a pipe 6 inches diameter, with a fall of 1 in 800; practice shows that, under the same conditions, 47·2 cubic feet will be discharged.

Will you give an example of the practical value of this when it is required to carry out drainage works over a very flat surface?—An inclination of 1 in 800 gives only 14 cubic feet per minute according to theory, while, according to actual experiment, and with the same inclination, 47 cubic feet are given.

Then this difference may be converted either into a saving of water to effect the same object, or into power of water to remove feculent matter from beneath the site of any houses or town?—It may be so.

And also the power of small inclinations properly managed?—Yes. For example, if it was required to construct a water-course that should discharge say 200 cubic feet per minute, the formula would require an inclination of 1 in $60 = 2$ inches in 10 feet; whereas experiment has shown that the same would be discharged at an inclination of 1 in 200, equal to $\frac{5}{8}$ths of an inch in 10 feet, thus effecting a considerable saving in excavation, or a smaller drain would suffice at the greater inclination. The practical importance of knowing the precise value of inclination is incalculable, and will be found so in laying down drainage for a flat district, or through loose and wet soils, where the extra labour in excavating the last few inches in depth to obtain a given level will often exceed in cost as many feet. I have frequently met with such cases. To name one, I will state that, during the progress of a sewer contract I had in 1842 for the Commissioners of the Holborn and Finsbury district, the depth of the trench was about 9 feet, and perfectly dry; the cost for labour was 8*d.* per cubic yard; the invert of the sewer, according to the levels given by the surveyor, required to be about 6 inches lower, and this proved to be in a running sand of the most troublesome nature, and cost me at the least 10*s.* per yard in the removal before the invert could be laid down.

Then all these experiments tended to the reduction of the quantity of water necessary to effect good cleaning, and removal of soil and matter held in suspension?—It would

And render more manageable works of drainage with comparatively small power, and make it more efficient and much cheaper, with properly constructed machinery?—Yes.

Mr. Hawkesley's tables are, I believe, taken as embodying the current and most recent formulæ before the institution of the trial-works, and were in practical use by engineers, &c.—They were of the highest authority; but the results I have given have been verified by a variety of experiments.

At the highest ordinary storm rainfall, what extent of roof would a 3-inch pipe and 4-inch pipe respectively keep clear?—Taking the rainfall to be two inches, a 3-inch pipe, laid at an inclination of 1 in 60, would convey away the water from 47 squares of roofing = 4,700 square feet; a 4-inch pipe under the same circumstances would carry off the rainfall from 98 squares of roofing = 9,800 square feet.

Mr. Roe, the chief surveyor, in a former examination in relation to some trial works, was asked how he found them agree with the theories and common practice of engineers? He answers—

Taking the Table, No. 1, I find that the size recommended for sewers to drain certain portions of land are larger than the actual requirements; for instance, the quantity of acres that a cylindrical sewer, 48 inches in diameter is, by the table, allowed to drain, when the inclination is 1 in 240, is 47. Whereas, in practice, it is found that such a sewer, with that inclination, drains more than 100 acres of town area, at a similar fall of rain to that on which the table is formed. Again, a sewer with a similar inclination to drain 129 acres of town area should (by the table) be of the capacity of about 28 feet, but in the great storm of August, 1846, the water from 215 acres of town area, and 1,785 acres of rural district, occupied only 30½ feet of the superficial area of a sewer with that inclination. With respect to larger sizes, the table shows that at an inclination of 1 in 480, a sewer to drain 329 acres of town area should have a capacity of about 78 feet; whereas, in a sewer with a similar inclination, the area occupied in the storm of 1844 was only 79 feet; and to this sewer there drained 1,181 acres of town area, and 2,656 acres of rural district.

By frequent urgings these experimental results have been practically tried in so large a number of houses, under such varied and, in many cases, disadvantageous circumstances, that no doubts whatsoever can remain in the minds of competent and disinterested persons on the point now immediately under consideration; namely, the efficient self-cleansing action of well-adjusted tubular drains and sewers, even without any additional supplies of water.

Mr. Lovick was asked—

"Since the commencement of the Commission have you had sufficient experience of the run of water through 3 and 4 inch tubular house-drain pipes to speak with confidence of their power to keep themselves clear by the ordinary discharge of the soil-water or drain-water of the house?—A great number of small 4-inch tubular drains have been laid down in the several districts, some for considerable periods. They have been found to keep themselves clear by the ordinary soil and drainage waters of the houses. I would refer to 15 houses in the cloisters at Westminster Abbey, which have now for upwards of 14 months been drained by small stoneware pipes, varying in diameter from 3 and

4 inches for the houses to 9 inches for the outlet, and which have acted, and continue to act, in the most perfect manner. I have been furnished by Mr. Morris of Poplar with blocks of houses in his district drained by small pipes; these are shown on the accompanying plans. No. 1 is a block of 12 houses in a court, six on each side; each six are drained *at the back* by one 4-inch pipe. They are connected with the closets, one to each house to which the water *is not* laid on, the water being thrown down them by the inmates. The only other source of supply is from the overflow of the butts in the yards, yet the pipes have kept themselves clear from the period when first laid down, now upwards of 13 months since, to this time, and are still acting efficiently. Plan No. 2 shows various blocks with combined back drainage by small pipes. Some have connexions with closets to which water is laid on, others take the overflow from privy cesspools; yet with these disadvantages, and with the further one of inferiority in the pipes in the early manufacture, these combinations of back drainage have been, and are now, all in successful action. They have been laid down, in one instance for upwards of two years, in the majority for upwards of 12 months.

Then you have no doubt that pipes of this kind will keep themselves clear by the ordinary discharge of house-drainage?—I have not; assuming, of course, a supply of water, pipes of good form, and materials properly laid, and with fair usage.

You have had other experience of blocks of houses where tubular drains have been laid down?—I have.

One of the earliest illustrations of this system was given in the improved drainage of a block of houses in the cloisters of Westminster, which had been the seat of a severe epidemic fever. Beneath that block of buildings where the fever raged was a network of old drains, sewers, and cesspools, all of which were filled with decomposing refuse. The inmates were at various times afflicted with foul smells, and 150 loads of night-soil were taken out of the cesspools belonging to 15 houses attacked with the epidemic, and upwards of 400 loads of refuse from the drains and sewers connected with them. The cesspools and the old drains were filled up, and an entire system of tubular drainage and sewerage substituted for the service of that block of houses. The consulting engineer thus reported in conjunction with Mr. Lovick the surveyor in June last, on the efficient working of these drains.

In a report made in June last on this block, by Mr. Austin

and myself, we state—"The delay has afforded us the satisfaction of reporting at the same time the complete success which has attended this work. The Dean of Westminster gave special instructions to the clerk of the works, resident in the Abbey precincts, to examine and report the condition of the drainage weekly; and not a single case of complaint has occurred during the whole period, except in one instance from an inconvenience which arose from the want of a connexion to a water-closet, not known at the time, and therefore not provided for. One of the 4-inch branches has recently been opened to make this connexion, and it was found as perfectly clean as when first laid down." The Dean of Westminster, in a letter on the state of this drainage, says—"I beg to report to the Commissioners that the success of the entire new pipe-drainage laid down in St. Peter's College during the last 12 months has been complete. The clerk of the works has examined every water-closet once a-week, and entered his written report in a book laid every Wednesday before the Dean and Chapter, and not one case of failure or imperfect working has occurred. I consider this experiment on drainage and sewage of about 15 houses to afford a triumphant proof of the efficacy of draining by pipes, and of the facility of dispensing entirely with cesspools and brick sewers." And up to this time they have acted, and continue to act, perfectly.

The working of this system, as appears by the Dean's report, and as I am informed by others, and from my own observation, has been completely successful. The smells, which were very prevalent under the old system, have not been experienced under the new, and I am informed that during the past year, a year of great mortality, this place has been remarkably exempt from sickness.

Mr. Morris, a surveyor attached to the Metropolitan Sewers Commission and acting for one of the most depressed districts, gives the following account of the action of trial-works of improved house-drainage very imperfectly executed within it:—

The Metropolitan Sanitary Commissioners are desirous of ascertaining what extra quantity of water will be required beyond the common supply for house-drainage under the improved system. Have you not within your district a block of houses which has been drained with tubular drains?—Yes, between 20 and 30 blocks of houses.

Will you give a specimen of one?—Yes; there is a block of 12 houses which has been drained with 4-inch glazed pipes, leading to a 6-inch drain in the road. These houses are supplied by the East London Waterworks, on the intermittent system, and the drains have been 12 months in action.

Take the case of a large brick drain at the same inclination as the small tubular drain, what do you find in practice?—In the large brick drain I find as the result deposit constantly accumulating, which the ordinary supplies of water are wholly inadequate to prevent. The water that does not escape through the open or imperfectly made joints of the brickwork is rendered almost inoperative by being spread over a large area.

Then the inference is, that with the present supply of water the small tubular drain would be self-acting, and that the large brick drain would require a constant flushing power to remove the accumulated deposit?—Yes, such would undoubtedly be the case, as the house-drains, where there is a water-closet attached, are periodically under the influence of flushing, by the use of the closet and the emptying of slops in the course of the day. On washing-days, sudden rushes of water thrown down the sinks furnish a very powerful means of flushing and removing obstructions; and every shower of rain, where the stack-pipes are judiciously placed in reference to the house-drains, is a powerful concomitant to the efficiency of a *non-absorbent* tubular system of drainage, in which not the least quantity of water that finds its way into the drain will be uselessly expended.

It is clear to you, then, that the small tubular system of drainage will require a much less quantity of water than is required for the existing system of brick drains?—Yes, quite so. In practice we invariably find such to be the case; as in the tubular system the whole of the water that is sent down the drain would be brought to act upon the deposit, which would be suspended, and thus prevented from accumulating; on the contrary, in brick drains very little of the fluid finds its way to the outlet of the drain into the sewer, being absorbed by the material of which the drain is composed—generally of place (or imperfectly-burnt) bricks—or percolating through the numerous open joints of the brickwork, leaving the more solid portion of the sewage to become indurated, and ultimately to choke the drain.

Mr. Grant, the surveyor who, under the Metropolitan Commission of Sewers, has charge of the Surrey districts, and who was directed to examine and report on the action of all tubular drains under his charge which had been in action for a sufficient period of time, attests their general efficiency, and applies the data thus incontestably established for complete works of sanitary improvement, combining with works of water supply the requisite apparatus for its removal, as described at length in his important evidence.

Of the present most imperfect drainage apparatus on the site of the Metropolis as well as of other towns, the cesspool occupies, on an average, about one quarter

of the evaporating surface, the house-drain about one-half, and the sewer before the house the remaining fourth. So difficult is it to obtain requisite attention to the subject even from those who ought to be responsible; so slow are the most palpable truths in making their way, that notwithstanding the early demonstration of the primary importance of house-drains, street sewers are still considered to be the works most requiring attention. It was demonstrated that sewers, unconnected with house-drains, and house-drains, unconnected with supplies of water, were only extended cesspools and nuisances; yet more money was constantly expended in laying down sewers on the old conditions, and it is still maintained by the officers habituated to the old practices who continue charged with the execution and superintendence of these works, that they should concern themselves only with what they call the main portion of the apparatus, the street drain or sewer.

The experience gained from the use of small pipe sewers, as laid down in numerous blocks of houses, and also from the important trial works, executed under the unfavourable circumstances of a defective supply of water, shows:—firstly, that as respects three-fourths of the apparatus requisite for the discharge of waste soil-water, and refuse in suspension, properly constructed works ought to keep clear of deposit, require no additional supplies of water, permit no accumulations, and need no intermittent flushings; and secondly, that the fact of any deposit being accumulated in house-drains beneath habitations, to decompose and evolve noxious gases, supplies conclusive evidence of the imperfection of such works, and the neglect or incompetency of those persons charged with their construction, inspection, and maintenance

In submitting the results of experiment in relation to the remaining portion, viz., the fourth constituted by the sewer, it should be borne in mind that, the evil of extended cesspools, house-drains, and sewers, constituting, for London, an evaporating surface represented by a canal thirty feet wide and forty miles long, giving off noxious exhalations amidst

streets and houses (varying in copiousness with barometrical conditions, being most copious when the barometer is low and the population most depressed), mainly arises from the non-adjustment of the drains, main and branch, and the waste pipes, to the run of the waste or polluted water; and from the neglect to economise power or diminish friction by attention to the forms as well as inclinations of that apparatus. This is everywhere displayed in relation to the most important discharges, that is to say, the smaller and the most frequent. House-drains are commonly constructed of brick spread over flat and rough surfaces, by which flow is retarded, and deposit occasioned. This process is often aided by the permeability of the drains, which let much of the water through, the insoluble portion remaining behind as deposit. The reduction of friction or gain of power for the discharge of the same quantity of water by adaptation of sizes of drains, may be stated in the following form, from the examination of the officer appointed to execute the trial works:—

What is the amount of friction to be ascribed to those pipes respectively?—The frictional line, or line in contact with the water, when the pipes are half full would be—in the 3-inch pipe 4·71, in the 4-inch pipe 6·28, in the 6-inch pipe 9·42, in the 9-inch pipe 14·13 inches.

What must be the major and minor axes of an ellipse which shall give an equivalent hydraulic depth to that of a 3-inch, 4-inch, 6-inch, and 9-inch pipe?—

Drains, inches in diameter.	Axes of Ellipse.	
	Major. Inches.	Minor. Inches.
3	3·6	2·5
4	4·6	3·5
6	6·8	5·3
9	10·4	7·8

What amount of friction would be due to each of those elliptical sections?

In the 3-inch pipe . .	9·74	inches nearly.
,, 4-inch ,, . .	12·85	
,, 6-inch ,, . .	19·13	
,, 9-inch ,, . .	28·9	

In respect even to the larger sewers evidence was adduced to show that by an alteration of their form from the flat bottom, or flat segment, to the semicircular or elliptical with the same inclinations, and the same runs of water, they may be kept comparatively clear of deposit. Nevertheless, we have had brought to our notice the following statement, made in August 1848 in a report to the Corporation of the City of London by Mr. J. Walker, Mr. W. Cubitt, and Mr. I. K. Brunel, on the sewers constructed under the City Commission:—

On the subject of the shape of the sewers, our own observation from the specimens we have seen, confirmed by that of our assistants, Messrs. Munday and Scott, and of Mr. Haywood, leads us to conclude, that the particular shape has very little indeed to do with the clearing away of the deposit; certainly very much less than is supposed or alleged by the respective advocates of the several shapes proposed. We think, that the clearing is regulated in a small degree by the size; but more by the positive quantity of water, and the inclination of the drain.

But although in strict theory the velocity of a given quantity of water running in the bottom of a sewer of the same height, width, and elevation, will be greater in the narrow-bottomed or egg-shaped than in the circular, it does not follow as a necessary consequence, that this greater velocity or greater depth of water will more effectually carry with it grit and sand that collect in the bottom. Practically the wear of the flatter sewer will be more uniform; and, as we have observed, experience has proved that the shape but little affects the deposit, while in other respects the flatter shape has advantages. So much are we impressed with this opinion, that in place of advising an invert more pointed and contracted than the semicircle, we should recommend the trial of a flat bottom of stone or other hard material, 14 inches broad, for a sewer of 3 feet in width at the springing of the arch, and 5 feet high, as more likely to keep itself clear, less subject to unequal wear, and certainly very much more convenient for being cleansed.

They repeat this expression of their opinion in their conclusions—

That the form of sewers has practically very little to do with the general question of their keeping clear of deposit, this depending very much upon their fall and the quantity of water; but that no fall or quantity of water is likely to be obtained, even in the city sewers, sufficient to keep them clear of obstructions, without the occasional aid of men in the sewer to remove hard deposit.

They state—

That there is a considerable quantity of soft deposit in some of the sewers; but that the fall or inclination in the private drains is generally such as to keep them clear of offensive matter.

This statement as to the general condition of the drainage in the City is so widely at variance with the evidence of medical officers and others, as to lead to the conclusion that these engineers have trusted to the reports of others by whom they have been misled, and that they could themselves have only examined some imperfectly selected portions of the whole works.

It follows, however, from the application of the doctrine of hydraulics which these engineers enunciate, that accumulations must take place in the sewers, and that these must from time to time be removed as at present by flushing, for which additional supplies of water will be necessary. These gentlemen see the insufficiency of even such supplies to effect complete cleansings, for they provide for the removal of accumulations and obstructions within the sewers by hand labour, and express a decided opinion that the sewers should be of such a size "as that a man can conveniently walk along. If the operation, (*i. e.*, of removing accumulations,) be too laborious, he will avoid the task, as our short experience proved."—p. 26.

They recommend reservoirs for intermittent flushings, in cases where the evil of accumulations arises in a fifth class of sewers.

From there being dead ends or summits, the reservoir or tanks, as constructed in Newgate and Leadenhall markets, would, we are convinced, be effectual in cleansing away all soft matter, as they have been in the above two cases, which have both been executed this year, care being taken that the operation be frequently repeated, and that men be employed in the sewer with proper tools to aid in disturbing and carrying down the offensive matter. The plan is excellent, and justifies the expense of an increased number of reservoirs or tanks, whenever they can be applied with effect.

The larger the supply of water from the water-works for this special purpose, or for the use of the houses that drain into any of the sewers, the better, for we think, that no water which is brought into a city can be considered as wasted or useless.

If the Thames, the Colne, the Lea, or any other stream, could, without prejudicing other interests, be brought through the me-

tropolis in a considerable quantity like the Alster in Hamburg, or if reservoirs could be formed to collect the surplus water from the country brooks, and run it through the sewers, the effect would be very beneficial. A plan of this kind was recommended for the Surrey sewers by the surveying officers (Mr. Horn and Mr. Walker), to whom the Bill, then before Parliament, was referred. That we agree as to the desirableness of an increased supply of water for scour, has been already seen by our Report.

But in opposition to these views, the experiments already cited show that properly constructed tubular house-drains are kept clear by the action of the ordinary water supply; and it follows that tubular sewers at proper inclinations, liable, in proportion to the concentration of the flow, to less friction and having consequently more power, would be kept clear more completely. And so it was proved by experiments similar to those made on house-drains. For example, a trial work with a tubular sewer was conducted under the direction of the Metropolitan Commissioners of Sewers, of which the following report was given by Mr. Hale, the officer who conducted it.

The main line of sewer in Upper George-street is 5 feet 6 inches high and 3 feet 6 inches wide, and runs from the Edgeware-road to Manchester-street, where it falls into the King's Scholars' Pond sewer. I have laid a 12-inch pipe 560 feet long into the invert of this main line, and built a head wall at the end of it, so that the whole of the sewage discharged by the collateral sewers above the pipe, as well as what sewage may find its way independently into the upper part of George-street, is forced to pass through the pipe.

The whole area drained by the sewers running into the 12-inch pipe in George-street is 213,778 square yards, or about 44 acres. Observations have been continually made on the work, and the results are as follows: The velocity of the stream in the pipe has been observed to be four-and-a-half times greater than the velocity of the same amount of water on the bed of the old sewer. The pipe has not been found to contain any deposit, but during heavy rains the stones have been heard distinctly rattling through the pipe. When the pipe is nearly filled, the velocity and concentration of the water are sufficient to clear away any matter which may have been drawn into the pipe from the large sewers, and much of which matter it may be presumed would never enter a well-regulated system of pipe sewers; also the force of the water issuing from the end of the pipe is sufficiently great to keep the bottom of the old sewer perfectly clean for 12 feet in length;

beyond this distance a few bricks and stones are deposited, which increase in quantity as the distance from the pipe increases. Beyond a certain distance mud, sand, and other deposits occur to the depth of several inches, so that the stream there is wide and comparatively sluggish, and being dammed back by the deposit, exerts an unfavourable influence on the flow of water through the pipe. On the invert of the original sewer, which now forms the bed of the pipe, deposit was constantly accumulating, and was only partially kept under by repeated flushes. The superficial velocity of the water in the pipe is generally three, four. and five times greater than the superficial velocity which obtained *under the same circumstances*, in the original sewer, and the velocity of the *whole mass of water* in the pipe approximates much more to its surface velocity, as ascertained by a float, than does the velocity of the *whole mass* of water in the sewer approximate to its own surface velocity.

On one occasion I had the sewer in Upper George-street carefully cleaned out immediately below the pipe, and then caused a quantity of deposit, consisting of sand, pieces of bricks, stones, mud, &c. to be put into the head of the pipe ; the consequence was, the whole of the matter passed clear through the pipe (560 feet long), and much of it deposited at some distance from the end, on the bottom of the old sewer. When the pipe was flowing nearly half full, two pieces of brick, one weighing one pound and three-quarters, and the other one pound thirteen ounces, were impelled by the force of the water through the whole length of pipe, and struck the legs of the man at the end of the pipe with considerable force. A live rat was also washed with great violence through the pipe, and struck the legs of a man with such force as proved the rat had no control over its own motion. When the water was only 5 inches deep in the head of the pipe, nearly a whole brick, weighing four pounds, was put in it; it was heard for a few seconds moving down the pipe, but was not caught at the end. (The bulk of water at the head of the pipe is diminished to half its dimensions when it arrives at the end.)

A great number of irregular-shaped stones, each of several ounces weight, were washed through the pipe with the same apparent ease as marbles, and the distinct rattling noise I occasionally heard them make might convey a correct notion of the considerble force with which they must have been impressed.

All the foregoing results were effected when the pipe was either only or less than half full of water, which have been gauged in the pipe. The following is a statement of the quantities of water:—

September 28 and 29.—Very wet both days and nights; there was at this period 96 hours' continuation of rain, and the pipe was never observed to be more than half filled.

October 19.—Morning, depth of water in pipe, 3 inches; afternoon, depth of water in pipe, 2 inches.

October 21.—Heavy rain, and rain all day; depth of water in the pipe, 4 and 5 inches.

October 23.—Morning, 3 inches; afternoon, very heavy rain, when the pipe filled.

October 24.—Morning, depth varied from 2 to $2\frac{1}{2}$ inches; afternoon, from $2\frac{1}{2}$ to 3 inches.

October 25.—During the day, depth of water varied from 2 inches to 3 inches.

October 26.—Morning, depth varied from 4 to 3 inches; afternoon, from $2\frac{1}{2}$ inches to 3 inches.

During the above three days the weather was mostly fine. The *considerable* variations are due to the times of the water being "on" at the houses; the sewage at such times is much clearer, as well as increased in quantity.

October 27.—On this day a storm occurred, which for a short period was very violent, the waters filled the pipe and rose above it 18 inches, but did not reach the top of the head wall; when the waters had obtained this maximum height, they receded to nearly the level of the pipe in 20 minutes.

October 28.—Depth during day varied from 3 inches to $1\frac{1}{2}$ inches.

October 30.—Ditto, 2 inches to $2\frac{1}{2}$ inches.

October 31.—Ditto, $1\frac{1}{2}$ inches to 2 inches.

November 1.—Variation of depth, from $1\frac{1}{2}$ inches to $2\frac{1}{2}$ inches.

November 2.—Ditto, 2 inches to $2\frac{1}{2}$ inches.

The result of these experiments, with others of the same kind, lead me to conclude that a certain current of air in drains and sewers invariably accompanies the stream of water, and that the latter causes the former, but that with regard to the *main body* of air in the present sewers, it is generally more influenced by local currents introduced through ventilating necks, gully shoots, man-holes, and side entrances, than by the ordinary small streams of water, and I am disposed to think, from experiments made with flames, that the currents of air up and down the private drains are regulated by these local currents and by the difference of temperature existing between the atmosphere in the sewers and the air in the houses, rather than from any supposed pressure arising from the rapid generation of gas.

The house-drains connected with the experiment in George-street, are in most respects like the rest of the house-drains of the metropolis; the conditions which mark the general character of the whole are great size, irregularity of form, and filthy and bad-smelling condition. The variations in size are from nearly half a square foot to four square feet cross section, and the different forms include the circle, the square, and square bottom and sides with semicircular top; their inclinations seem not to vary more than from horizontal to a fall of two inches in ten feet. Their condition with respect to quantity of matter deposited in them

does not seem to be regulated by their inclinations. This may be accounted for by the fact, that their wide and irregular inverts spread the small streams and destroy their force, and cause matter to lodge with greater security. Many of the ends of the drains are so dilapidated, that their original form cannot easily be distinguished; but enough can be determined to know that the sum of all their areas (480) would exceed the area of a circle of 30 feet in diameter.

Much of the rubbish and obstructions in the house-drains have been found to consist of heaps of pieces of brick and mortar which from time to time have fallen from the soffits and sides of the drain, as it has progressively become dilapidated. Various species of fungi shoot out from the interstices of the brickwork; and the existence of old cobwebs around the sides, and sometimes nearly covering the mouth of the drain, furnishes another proof, in some instances, that the drain has not been for a long time, if ever, half filled with water. These old drains are the special harbours of rats and other vermin.

In the trial works at Earl-street, conducted by Mr. Lovick, the most accurate gaugings were obtained of the flow in a sewer having 15 feet sectional area with a flat segmental bottom 3-feet wide, where deposit was found to accumulate at the rate of 6,000 cubic feet in 31 days, from 1,200 houses.

In this sewer a pipe of 15 inches diameter laid along the bottom, at a somewhat less inclination than the sewer but with the same run of water, remained perfectly clear of deposit. The like results were obtained at other places. An estimate was directed to be made of the expense of laying down a mile of 16-inch pipe in an old sewer, with junctions of 4-inch branch pipes to every house-drain made good, when it was stated that the expense would be 254*l.* 14*s.* 5*d.* per mile; and it appeared that in many such situations as those where, according to the views of Messrs. Walker, Cubitt, and Brunel, cleansing by flushing or hand labour would be required, such a line of pipe would keep the sewer entirely clear of deposit, and, so far as the sewer itself was concerned, clear of smell, while it would greatly diminish, if not prevent, the circulation of foul gases from the house-drains through the sewers. According to the report of Mr. Lovick the present expense of flushing in some districts is 2*l.* 10*s.* per mile per week. In the newly-cleansed

districts it was 29*l.* per annum per mile. Even this expense was owing to old accumulations now in course of removal. In the Holborn and Finsbury division, where the flushing is regular, the average expense of keeping the sewers clean by flushing, at piece work, is 17*l.* 5*s.* per mile per annum.

Now, the total cost (under proper arrangements for manufacture and execution of the work), of such a tubular sewer as that above described by Mr. Hale, allowing for a 16-inch pipe instead of a 12-inch one, and spreading the payment over twenty years, would not be more than 19*l.* 8*s.* 5½*d.* per mile per annum.* Under the flushing system in the least uncleanly sewers' district, the expense of flushing represents the expense of removal of 517 loads of detritus and decomposing refuse at 8*d.* per load, spread in portions over a mile of surface 3 feet wide on the average, until it is removed at weekly and fortnightly intervals. At an extra expense of 2*l.* 3*s.* the retention and spreading of a proportionate part of these 517 loads may be prevented in streets where there happens to be a sufficient fall.

From observations made in Liverpool, at the outlet of Beacon's gutter-sewer, it was found that the water was only 20½ inches deep after 12 hours of heavy rain.

The area of drainage into that sewer is 983·3 acres,

---

* *Vide* Appendix, Mr. Gotto's evidence of trial works in improved manufacture of pipes and hollow brick for arching, from which will be seen the reduction of cost which may be effected in the accessories of drainage as well as in the pipes themselves. The following comparison is given of the cost of gully shoots under the old system, and of that at which they may be constructed :—

	£.	s.	d.
"As constructed in the City	12	16	10
As constructed in the Westminster District in 1839	7	17	6
Ditto, in 1845	4	4	11
Of 9-inch stoneware pipe, at the present time in the Westminster District	3	17	0½
Of 6-inch stoneware pipe, at the present time in ditto	3	5	4
As they may be constructed of red earthenware pipe, 6 inches in diameter	1	10	0
As they may be constructed of 4-inch earthenware pipe, by contract, under the Commissioners	1	7	0."

The proposed reduction of the price of gully shoots will be of great importance for suburban road drainage and road construction.

of which about one-fourth is built, and three-fourths unbuilt. Now, by the most approved existing formula, the diameter of sewer necessary for this drainage, with the given fall, would be 10 feet, while the actual diameter of the sewer, at its largest part, is only 4 feet 6 inches, and the depth of water in it was somewhat less than a third of its longest axis, even after the continuance of heavy rain for 12 hours, when it may be reasonably supposed the whole earth would be saturated and every drop of rain would flow into the sewer. The sectional area of the sewer occupied was less than one square inch for each acre drained. Calculations for the capacity of sewers where they have been made at all have proceeded on the assumption that it is necessary to provide under all circumstances and in all positions for the contingency of rain floods almost incredible. Mr. Hawksley's tables are estimated for the enormous fall of 2 inches depth of rain in an hour. Now that such a flood may occur is possible, although even this possibility has been very much disputed; but it would be easy to show that if it did occur there is no necessity to make general provision for these excessive storms; that it is in the valley lines only, the lower points of districts, where the waters naturally meet and accumulate, that such provision should be made; and it requires merely a glance at the streets of a town built on sloping ground, like Liverpool, during even a moderately heavy rain, to be convinced that a great part of the rain drains directly by the surface of the street into the river and never enters the sewers.

As the old formulæ, now in use, are founded on imperfect data and experiments, and not only give results so far above what experience shows to be the fact, but which, even if they were correct, would be of most limited application, they are obviously uncertain guides, and it is better to trust to our observation of what actually takes place. This, in fact, is experimenting on the largest and safest scale.

Any person using a bath may consider whether an 18-inch brick drain can be necessary to convey away the

fluid refuse of the largest house, by merely watching the flow of water out of his bath. Supposing the bath to contain as much as 150 gallons, the whole volume of water will be passed off in 12 minutes through a pipe 1-inch in diameter, and this same 1-inch pipe would, at a similar rate, deliver, during the 24 hours, about 18,000 gallons of water; which, calculating 100 gallons as the supply or waste of each house, would serve 180 houses. Now, it must be remembered, that the use of a pipe 4-inches diameter is advocated for house drainage, or a sectional area of discharge which is to the inch-pipe as 16 to 1. It is not, however, the volume of water or the amount of refuse to be passed with it through the drains which dictate this as the minimum diameter, but other considerations having relation to the free motion of the material from water-closets passed into these drains, and to the passage of storm waters.

Observation of the laws of moving waters, or the conditions under which water in slow motion deposits matter in suspension, or, with increased motion, lifts and removes first fine sand, then, with accelerated motion, coarser sand, then pebbles, then large stones, and lastly boulders and vast masses, and consideration of the inclinations by which velocities might be regulated, should have prevented such noxious as well as expensive errors as are displayed in the sewerage arrangements for the relief of towns. Much of the practice of those engineers who have given evidence in favour of large sewers of deposit ought to have taught them better. Where, to cleanse a harbour, dock, or basin, the scouring power of water is resorted to, sand, mud solidified, and shingle are carried out by a narrow and confined stream of water being gradually brought to bear upon the broad accumulation. But, it has been noticed to us that Mr. Rendel proposed to preserve deep water up to the gates of the Birkenhead Dock, by letting out a thin sheet of water, at a depth of 20 feet over the whole area of the entrance, which should give one uniform and continuous scour out into deep water in the river. The practice of intermittent scouring may have led these engineers away from the considera-

tion of the continued action so necessary in sewers and drains, and so easily attainable where the outlet is preserved free. In docks and basins deposit cannot be prevented, but in the gate entrances no such accumulation is allowed to take place. One other example may serve to illustrate the power of water in constant motion to remove refuse; canals are necessarily level throughout their several reaches, the only draft or outlet being through the locks; in their comparatively sluggish streams deposits take place as in large flat sewers; such was the case in the Bridgewater Canal, until the swift boats commenced running; the passage of these, at high velocities, put the whole body of water in motion, and although the flow towards the locks or outlet at Runcorn does not exceed one mile per hour, the whole of the mud was passed on towards them, and at the annual stoppage the bottom of the canal was found to be as clean as if swept with a broom.

When the flow of water carrying away the granite detritus of macadamized roads is arrested, and the detritus settles, it commonly becomes so indurated as to require force to separate it for removal. It appears a very defective arrangement to allow deposit to go down into such receptacles in order to be lifted up again at much labour and expense; and in the Sanitary Report, a cesspit was proposed for the gully shoots to road drains, to prevent such deposit going down. The tubular main drains were, however, commonly laid down without this precaution.

Mr. Lovick was asked—

Have the pipes which you have put down been in macadamized roads?—There have been some put down in roads of that description.

Have they any protection from granite detritus?—Some of them have not.

And yet they have kept themselves clear?—In those cases in which the pipes have kept themselves clear there has been a good flow of water, and they are laid at a good inclination.

Does it not appear that with a tolerably strong flow in the main-line, if the stuff from roads was sent into it it would be carried off?—With the main-line laid at a due inclination, and with a good flow of water through it, the slop from the roads in

wet weather would, I believe, be carried off; but hitherto there has not been a sufficiently large experience on this point to speak with absolute certainty.

In other instances the trial works were made with old drains and apparatus laid down in the most rude manner. Thus, in one instance mentioned by Mr. Morris, where 150 houses were drained perfectly through one 6-inch unglazed earthenware pipe, he was asked—

Do all the houses drain into it?—They do; the drains are all old drains. The 150 houses drain into it, and about 10 of them have water-closets.

How is this earthenware pipe laid down?—It was laid down without any care, and connected with a 14-inch drain from the houses, and when it was accidentally stopped, from the pipe having broken, it was found that this drain had been in use for 17 years. All the drainage of this large block of houses must have been gradually carried into it in the course of years.

According to Messrs. J. Walker, W. Cubitt, and I. Brunel, and judging by the actual works within the City of London which they approve, this block of houses should have been drained by a sewer large enough for a man to go up, or one 4 feet by 2 feet 6 inches wide. In some of the old sewers' districts courts of six houses are so drained; whilst, as already shown, one 4-inch pipe drains an equal number satisfactorily. If the block of 150 houses had been drained by a sewer of the size and shape which those engineers approve, there would undoubtedly be a constant accumulation taking place which would necessarily require a man to go up to remove it by hand.

Taking the quantity of pipe water delivered to a town, the amount of which is easily ascertained, as the measure of the soil or waste water which requires to be removed, better approximations might have been secured than those which are presented as justifications of the accumulations of decomposing matter beneath streets and houses. It appeared from the gaugings of the run of water on ordinary days (and exclusive of storm-water), that the drainage of 1,200 houses occupied a space not larger than would pass a 5-inch pipe, proving that the actual drainage of 1,200 houses would

go through a space less by two-thirds than that which on the advice of various architects was fixed by the Metropolitan Building Act as the minimum size of a drain for a single house. If, as appears probable, the flow of soil water from house-drains in the entire metropolis were in the same proportion, then the whole of the present soil or refuse water from the houses might be carried away in one pipe of 3-feet in diameter, and a double quantity in one 4-feet pipe. It follows, that a pipe of about one-tenth of that, or less than one foot sectional area, would convey away from the 16,000 houses comprised in the Corporation jurisdiction, all the soil water which is now spread over a multitude of large sewers. This is not put as rigorously accurate, for the discharge of soil-water would not usually be through full pipes, nor is it put as being applicable in practice, since provision has to be made in addition for storm waters. House-drains of the form and with the tubular junctions described in the evidence (*vide* Medworth), are found sufficient to carry away storm-water. It is proved, however, that whilst the house-drains, the capillaries, will require to be considerably diminished, the mains should be diminished in less proportions, and, on some of the sunk or valley lines, considerably enlarged for the reception of sudden discharges. But in the works approved by those engineers from whose report we have quoted, the adjustment for the reception of rain or storm-water in the branch streets or lines, was found to be almost as widely defective as the general arrangements for the discharge of pipe-water, if, indeed, they had ever been separately considered. Mr. Hale, who examined the City sewers for the surveyor to the Corporation, was thus questioned in relation to this provision—

You would make the course of the valley, the course of a sunk main, a river; in fact, receiving the mere rills and brooks of surface rain water as well as house-drainage?—Yes.

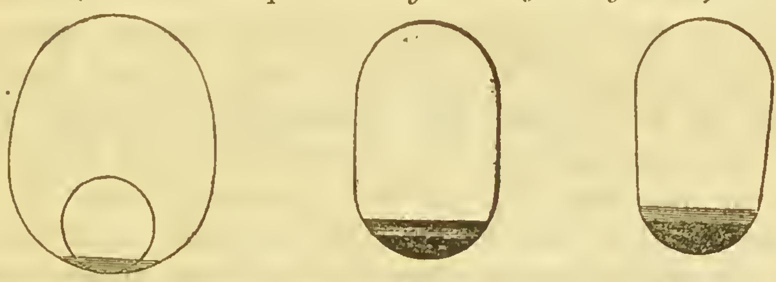
Might not persons, though not surveyors or engineers, by attending to the subject, considering carefully the work required, observing the run of rain or storm water on the surface of a street, have formed a tolerably correct notion of the size of sewers to carry it off?—It is my opinion that they certainly might, and

some persons at first sight form a much more correct notion of such a thing than other persons of less natural capacity who have been educated as engineers.

You have not yet formed an opinion as to how much you would reduce them with safety, as regards storm-water?—I think one-third. During great storms I have observed the waters flowing rapidly down well paved streets, but never exceeding the limits provided for them in the channels, although those channels being comparatively rough and flat-bottomed, were much less adapted for a rapid flow than smooth cylindrical pipes. We also observe that these storm-waters might generally be compassed by small pipes.

Upon the plans of sewers submitted by the City Surveyor, there appear to be the cross sections of three of the mains which you explored. Will you mark in pencil the height at which, according to your gauging, you found the average run of water.

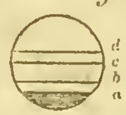
(*The Witness put in the following Diagrams.*)



Holborn. Golden-lane. Fleet-street.

Will you take the compasses and draw the size of a circular sewer which form it is presumed you would use with a regular run of water, and describe the sizes in which such ordinary run might be contained, leaving space for the conveyance of what you think would suffice for the removal of storm-water.

(*The Witness put in the following Diagram.*)



Under the most disadvantageous circumstances, I think the 2-feet tubular drain would not be more than 3 parts filled.

Glazed stoneware pipe 2 *feet diameter* proposed to be used on Holborn-hill, in lieu of the present brick-built one, 5 feet 6 inches by 4 feet 6 inches. The level *a* shews the height or ordinary flow, *b* the presumed height after the admission of a drain from every house, *c* the height of storm waters without any discharge from houses, *d* the level during storm and discharge from private drains.

You have stated that any person not an engineer, might, from

the sight of the surface water in the streets, form a notion of the channels required beneath it, to carry away that same water; perhaps you have observed the space occupied by the surface water in Holborn on a day of a heavy fall of rain or a storm. Can you give in transverse sections of the streets and kennels, with the surface water on such occasions, and what the surface water on Holborn-hill would be if it were sufficient to fill the 20 feet sewer provided beneath?—The sewer in Holborn-hill would hold water enough to cover the entire surface of the street, to the depth of 6½ inches. The consequences of such a superficial discharge would be that the water would rise in the road above the level of the pavements, and flood the adjoining underground premises.

Supposing a volume of water equal to the contents of this sewer of 10 feet in sectional area, spread over the surface of Little Britain, would not that cover the whole street to some depth?—I think it would, and it would present such an appearance as had never before been seen in any street.

Besides the suggestion of the engineers above recited of bringing in another river or so, and applying it to cleanse the metropolis, several plans have been submitted for economising pipe water supplies by ponding up surface drainage water on the higher levels, and distributing it from reservoirs to keep the main sewers clean by flushes at proper intervals. But on a due consideration of the actual results of the trial works, and the other evidence, we find it to be proved conclusively—

That all regular or intermittent deposits of matter intended to be removed in sewers or house-drains, are occasioned by the defective adaptation of branch and main drains for removal of the waste water in respect of size, form, inclination, and material:

That where the water is properly and continuously distributed, and the channels for the removal of the soil water are properly adjusted for the purpose, those channels are kept clear by the ordinary flow of the soil water itself; that is to say, by less than one-half the quantity of water now passed through house-drains and sewers which accumulate decomposing deposits.

The attention of the officers directed to make the

important trial works was confined as closely as practicable to the operation of the drains in dry weather, and to the effects of the discharges of the soil water; and endeavours were made to ascertain, proximately, at what rate, and in what time, whole sites might be cleared of the semi-fluid matter which is in a condition to pass through the stages of decomposition and decay. Though the trial works were not on a sufficiently extensive scale for ascertaining with accuracy such rates and times, yet they sufficed to prove the practicability of attaining this most important sanitary object. In respect to the trial works connected with the Earl-street block of 1,200 houses, Mr. Lovick was asked—

It follows then, does it not, that if the house-drains kept themselves clear and the sub-mains also, that with the increased force gained by junctions at the proper inclinations, the mains also would keep themselves clear by the ordinary supply of their own water even in dry weather, and that there is no need whatever under such a system for additional supplies of water either for flushing or for keeping the drains clear of deposit?—In a system of house-drainage properly proportioned and laid at a due inclination, if the single house-drains, the branches and sub-mains, with the ordinary supply of water, keep themselves clear in dry weather by the continual concentration and acceleration of the flow, it follows, that by preserving a due proportion in the sizes to the flow and in the inclination of the mains, and with the increased force gained by proper junctions, the mains would keep themselves clear under similar circumstances, and that in such a system of house-drainage no additional supplies of water would be requisite for that purpose.

Under this system, and in this particular block of houses, supposing it were back-drained with tubular drains, what would be the greatest length of time that any decomposing matter discharged through the house-drains would remain beneath the site until removed into the trunk-main? what is the ordinary rate of discharge from any given point per hour?—I believe it may be safely estimated that, with the inclinations at command, the sewage would be removed from the extremity of the district, in the system described, into the main-trunk at this flow, in a period not exceeding 15 minutes. The rate of discharge along this line at the period named would not, I think, be less than three miles per hour; but this would be subject to infinite variations as the pipes were more or less full, or subjected to the influence of pressure.

There is a densely packed block of 282 houses,

near Hanway-yard, Oxford-street, which has now beneath it, as described by Mr. Cresy, jun., an almost permanent evaporating surface of "an *approximate* "extent of about 8,500 superficial feet, or about one-"fifth of an acre for the drains and cesspools over the "whole area of nine acres, but in a long inhabited site "of the kind under consideration, the whole soil "becomes charged with decomposing animal matter, "and for *in*sanitary purposes, presents an area of a "considerably greater extent than can possibly be "ascertained by the direct measurement of cesspools "and drains."

He was asked as to the effect which would be produced upon this depressing and pestilential site by a combination of works of water supply and drainage.

Within what period of time would any matter be completely removed from the site in question by the action of the drains you propose?—From the great acceleration of the flow induced by the concentrated back-drainage, I calculate that barely more than a minute would elapse, under ordinary circumstances, from the moment drainage matter enters the longest line till the moment it quits it.

Mr. Medworth was asked—

Taking a house-drain and its junctions, will you state within what time water discharged through it would get beyond the three-mile radius from the Post-Office, calculating with ordinary falls and levels, and the usual rate of discharge?—Suppose the house-drain to be of non-absorbent stoneware, the soil and slops from a house would leave the premises as fast as made; this, delivered into a main line of the same material and 12 inches diameter, laid with a fall of 1 in 240, and running full, would deliver the house-drainage beyond the limits specified in 45 minutes, the velocity of the stream in the main line being about four miles per hour.

Where appropriate arrangements are made for at once receiving such refuse as human excreta in water at a proper coolness of temperature, which arrests decomposition, it is proved to be practicable to remove it from beneath dwellings at the very commencement of the process of decomposition, and to convey it beyond the urban precincts before it can have arrived at the more noxious stage of decay; a condition which it must reach to a large and most injurious extent, under

any of the schemes which allow accumulations of refuse to be removed by intermittent flushings. The evidence last cited involves important considerations upon this topic, which we shall now endeavour to elucidate.

The practice which has been pursued by one engineer after another, and is followed in the report of the engineers we have cited, in relation to the city sewerage, of regarding almost exclusively that portion of cleansing works, which, with any plan of properly combined apparatus, is, as we have already stated, the least important, namely the conspicuous mains, has led to the overlooking of some of the most important defects of the existing plan, and the most obvious means of its improvement. These consist of the means of increasing the power and sweep of a given quantity of water, and augmenting the rapidity of its discharge, by shortening the channels, and increasing the falls.

One means of economising the power of water and obtaining a quick discharge of matter is to obtain from each house the shortest run and the greatest fall for the discharge of soil water ; but by carrying the sewers invariably through the centres of streets, as is done within the City of London, (with reference to which Messrs. Walker, Cubitt, and Brunel suggest no alteration,) the Commissioners subject the owners and occupiers of houses to the expense and inconvenience of the longest run and the least fall.

The delivery and chief use of water is into and about the back offices of houses, and the discharge of waste water must be from thence. To take the example of a single house of the fourth class. The table or level to which drainage may be carried being the same, if the drain were carried from the back kitchen under the front room and into the sewer in the centre of the street, and the rate of inclination were 1 in 120, the waste water could usually be carried into a main drain or sewer at the back of the house with an inclination of 1 in 30. The time of discharge from the back tubular drain will be to that from the front drain about as 1 to 4.

The loss of force from defective falls and increased

friction occasioned by the present engineering practice, is also accompanied by the loss of power caused by the bad junction of the house-drains with the sewer or main. At the commencement of the investigations under the Sanitary Commission, no rule was found in books, much less in practice, in works in the several sewers' districts, or in any engineer's plans of recent date, whether large or small, for determining the diminution of friction, or the gain of cleansing power by concentration of flow, and increase of velocity of a given quantity of water. Trial works were directed, to obtain information for future guidance. The results are set forth in detail in the evidence of Mr. Medworth, the officer who conducted them.

After the exposition in the Sanitary Report of some of the more prominent defects of the system of sewerage in use in the several districts of the metropolis, improvements in the forms of sewers were proposed to the Westminster Sewer Commission in 1846; but inasmuch as flushing apparatus was proposed in connexion with them, and as the houses were to be drained separately, with drains unnecessarily large and junctions at right angles, those alterations, though improvements, were deemed unsatisfactory, as masking and continuing a pernicious system which contemplated intermittent accumulations, for the removal of which flushing apparatus was provided, and further trial works were urged for adoption. The comparative results are carefully and accurately described in the evidence of Mr. Lovick, who superintended the trial works, made the surveys, and got out the plans and estimates in detail.

Give a comparative view as to the relative proportions, the economy, and the efficiency of these systems, viz., of the old system, of the system proposed in 1846, and of the new system of improvement by back drainage, in pursuance of the principles deduced from the investigations of the Metropolitan Sanitary Commission?—The diagrams handed in illustrate the comparative proportions of the three systems, and will elucidate their further description; taking the three systems in their several relations to each other:—

—	On the Old System. / On the Improved System of 1846.	On the Old System. / On the Improved System of 1849.	On the Improved System of 1846. / On the Improved System of 1849.
The lengths are as . . .	1 to 1	2¼ to 1	2¼ to 1
The inclinations of main sewers are as	. .	. .	2 to 1 nearly
The inclinations of house-drains are as	. .	. .	1 to 10
The sectional areas of mains are as	2½ to 1	30 to 1	11½ to 1
The sectional area of the single house-drain is as .	2¼ to 1	10 to 1	4 to 1
The capacity (cubical) of whole system is as . .	2½ to 1	37 to 1	14¾ to 1
The cost is as	2 to 1	8 to 1	3¾ to 1

Thus in the system of 1846, the sectional area of the main is 11½ times greater than the sectional areas of the mains according to the most improved practice, and its cubical capacity 14¾ times greater; the cost of the system being 3¾ times greater. The system of 1846 would form a reservoir for a rainfall of 1 inch in depth on the whole area drained. In the old practice the sectional area of the main is 30 times, its capacity 37 times, greater than the new; and the cost 8 times greater. The three systems would retain a rainfall on the area drained of 2½ inches, 1 inch, and one-fifteenth of an inch respectively. Thus the *economy* of back-drainage, as compared with the separate system of a centre sewer through the court, with drains from and through each house, would be—

—	On the Old System.	On the Improved System of 1846.
In the length	2¼ times	2¼ times
Inclination of main sewer . .	. .	2 ,,
Inclination of house-drains . .	. .	10 ,,
Area of mains	30 times	11½ ,,
Area of house-drains . . .	10 ,,	4 ,,
Capacities	37 ,,	14¾ ,,
Cost	8 ,,	3¾ ,,

Or four similar localities might be drained on the new system for the cost of one on the improved system of 1846, or eight for the cost of one on the old system.

State the comparative advantages of the back over the old and improved systems in regard to the acceleration of the flow, and the relative proportions of the flow in the two systems; and to the relief from stagnant refuse under the houses, and from the percolations into the strata?—The sewage in the new system has to move through less than one-half the distance than in either of the

other systems, in a more direct course, with far greater inclinations, in contact with smoother surfaces, concentrated in smaller drains, and with curvatures at the junctions opposed to the entries at right angles in the other systems; thus it will be discharged in a proportionately less period. Experiments would be required to ascertain the precise effect of these improvements, but a moderate estimate would give the discharge from the houses on the new system in one-fourth the time of its discharge through the system of 1846; or the sewage in the one system would remain four times longer *under* or in the *vicinity* of the houses than in the other. In the old, porous, sieve-like system the whole of the sewage *would not* be discharged or flow uninterruptedly to its outlet; but the more liquid portions of the flow would percolate through the joints of the brickwork, be absorbed by the surrounding strata, and sap the foundations of houses, rendering them damp and unhealthy; and would frequently contaminate wells, and would deposit the more solid and offensive portions which remain *under* the sites of the houses, frequently generating disease, until removed by breaking up the drain. So that there can be no estimate of the period of the discharge of the *whole* flow in this system, as this is an impossible occurrence. The economy *in cost* of the tubular back-drainage system would be greater if the cost of the necessary periodic cleansing of this system was taken into account, for accumulations would be forming almost from the first hour of its use, from the vast disproportion of the area to the flow; from the necessary roughness, irregularity of material, and formation; from the largely increased space through which the sewage has to pass; and from the diffusion of the flow over so many (in this case sixty-six) *separate* channels beside the main; whereas in the back system *two channels* concentrate the whole, accelerate it, and thus prevent accumulations.

In the drainage through each house, would there not be danger from the emissions of effluvia *in* the house, which would not be possible under the system where the drainage was carried at the back, at the farthest distance from the house? Is not there in the back system less disturbance of the floors of houses and of the public streets? Give a synopsis of the two systems?—In the old system there would not be any security from annoyance, or even positive danger, from its favouring *to the utmost* the escape *in* and diffusion *through* the house of the deleterious effluvia, which, sooner or later, will be emitted, but which, by the system of back-drainage, even if loaded with all the old defects, would have been largely warded off. The bulk of the drainage and the *most deleterious* portion is generated chiefly *at the backs* of the houses, and would, under the old system, be sent from thence *through* the house to the sewer *in front,* having to travel through the *greatest* possible space with the *least* possible velocity, and with the widest

diffusion of the flow. In the formation of the system the disturbance of the flooring, joists, and walls of the houses of the roadways and public streets, peculiar to this system, or of far greater amount than in the back system, to the annoyance of the inhabitants and interruption of public transit, is a consideration of much weight. The system of back-drainage is in every respect the converse of this system and of all systems founded upon this principle, and is in every respect superior to them: for it receives the sewage at the *farthest* possible distance from the houses, instead of bringing it *into* and *through* them; concentrates and accelerates the flow in a few channels, instead of diffusing it over many, with, in many cases, scarcely an appreciable velocity; removes all the decomposing noxious soil and drainage from the houses as it is produced, instead of, as in the old system, transmitting the liquids through to the strata, and retaining the solid and more offensive portions *under* and *around* the houses; is more easily executed, with far less trouble and annoyance, and at less cost; and practice has already established it as the most efficient.

Have you not practically found that 4-inch tubular pipes work best for house-drains?—Yes.

How much larger was the size of drains required for houses by the Building Act?—The *least* size required by the Building Act was *five* times larger.

Taking the block of twelve houses, drained by 4-inch pipes, which you have adduced as an example of the efficiency of small tubular back-drainage, state what would be the relative proportions of the system of drainage formerly practised in that district, and of the most approved system where the drains are carried through each house and where combined at the back?—The plan I now hand in shows the relative proportions of the systems referred to. In the old system there would be a large brick sewer through the centre of the court, with large brick drains *through* each house. In the improved system the sewers and drains would be of small stoneware pipes, whether carried through each house or combined at the backs of the houses. The collective areas of the systems would be—

The old	. . .	15·55 feet.
The improved (separate)	.	1·23
„ (back)	.	0·174

Or the old would be 13 times greater than the improved separate, and 89 times greater than the improved back system, and the improved separate 7 times greater than the back system. The capacities of the systems would be—

The old	. . . .	835 feet.
Improved separate	. .	52
Back	. . . .	14½

Or the old 16 times greater than the improved separate, and 57 times greater than the back system; and the separate between 3 and 4 times greater than the back system. The systems would retain a rain-fall on the area drained of about 4½ inches, ¼-inch, and $\frac{1}{13}$ inch respectively.

What would be the proportionate cost per house of these systems?—The cost of the sewers and drains only, excluding the adjuncts of closets and sinks, in each system would be—

	£.	*s.*	*d.*
The old	7	14	6
The improved (separate) .	3	1	10
" (back) . .	1	4	1

The old being two and a half times greater cost than the improved separate, and nearly seven times greater than the improved back system, and the separate nearly three times greater than the back system. With a velocity of only 3 feet per second, the extraordinary fall of rain of 2 inches depth on the area drained would be discharged by the small pipes laid at the back in twelve minutes, so that their adequacy to discharge the heaviest recorded falls of rain cannot be questioned.

Taking the water-supply to this block of houses, state the cost of the intermittent system as compared with the cost of the constant system, where the pipes are of lead, and carried separately through each house?—Excluding the closet apparatus, the intermittent 8*l.* 12*s.* 4*d.*; the constant system, 3*l.* 12*s.* 1*d.*, or less than half.

State also the proportionate expense of works for water supply on the constant system, where the pipes are carried through each house from the front to the back, and where carried at the backs of the houses?—Where the pipes are of lead, on the separate system, 3*l.* 12*s.* 1*d.*; on the combined back system, 1*l.* 10*s.* 9*d.*, or less than half.

Supposing these works of drainage and water-supply were executed in combination, what would be the gain per house, or what the loss, supposing them to be carried out independently?—The gain per house from the combination of these works would be, where the drains and pipes are carried through each house, 1*l.* 2*s*; where carried at the back, 7*s.* 2*d.*; but the proportions of saving to the total cost would vary with the materials employed.

Whilst the plans given herewith contrast the differences of lengths, the annexed view gives the relative sizes of the different sets of apparatus, the smallest being those which convey away the refuse without leaving any deposit, the largest being those which accumulate deposit. The officers who were directed to apply the principles were themselves astonished at the

gains in economy as well as efficiency, when they had completed their plans and estimates. One of the most important applications of the principles we have been enunciating is contained in a plan of combined works for water supply and drainage, which Mr. John Grant was directed to prepare for the sanitary improvement of a low-lying district in Bermondsey, from which epidemic disease is rarely absent, and which was most severely ravaged by cholera. This plan is most important, as comprising, in addition to the impermeable tubular drains for the removal of the waste water, a complete set of permeable agricultural tile drains for the removal of land-spring water, and other surplus moisture derived from the rainfall on the uncovered spaces; an arrangement which, notwithstanding the frequent exposition of its necessity, we find much neglected, even in the recent plans of engineers and surveyors, who undertake the execution of new works.

You were directed by the Works Committee to report on the means of the combination of the water supply with the house and general drainage works for the complete water supply, drainage, and cleansing of a block of houses comprising the fever-nest known as Jacob's-island, Bermondsey?—I was.

What was the extent of the block of buildings you so laid down? —The total area was about 50 acres, the area built upon about 41½. The number of dwelling-houses, 1,317; of granaries, manufactories, and buildings other than dwelling-houses, about 50 more; the average number of houses per acre being 32.

Will you state the sizes of house-drain branches and main or trunk drains you propose?—The house branches to closets are 4 inches diameter; to sinks 2 and 3 inches; the main lines are 6, 9, 12, 15, and 24 inches.

How many principal mains are there, and what are their sizes at the outlet?—There are four main drains; one measures at the outlet 24 inches diameter, to take the drainage of about 23 acres and 630 houses, besides making allowance for 10 acres and 670 houses more, which may be added at a future time. A second main line is 15 inches diameter at the outlet, to take the drainage of 10 acres and 364 houses, besides providing for 255 houses which may be added at a future time. The third main line is 9 inches, to drain 3¼ acres and 162 houses, besides providing for three-quarters of an acre and 107 houses more, which may be added. The fourth is 12 inches at the outlet, to drain 6 acres

and 177 houses, besides half an acre and 140 houses more, which may be added at a future time. Provision is made for still further, if required, concentrating the streams of drainage into one line.

Supposing that you had an order of Court for the execution of this combined work of water supply and drainage, within what time do you consider it might be executed?—From three to four months.

How much of the Surrey and Kent district might be with safety similarly drained in blocks separately, with the aid of the general and subterranean surveys?—All the more densely-built and most necessitous part might be similarly drained into the best of the existing sewers which surround the blocks. The outlets could be afterwards connected, and concentrated in the direction most desirable.

In this part of Bermondsey have you found many house-drains constructed under the former Surrey and Kent Commission?—Most of the houses drain into cesspools, but there are a few drains connected with the sewers in Great George-street and one or two other streets.

What was the size of house-drains made most recently before the late Surrey and Kent Commission?—9 and 12-inch brick barrel-drains; about three or four years ago 15 inches; and, if to more than three houses, 18 inches.

What is the area of friction in these drains?—If they were full, the area of friction would be, in 9-inch drains, 2·356 feet; 12-inch drains, 3·1416 feet; 15-inch drains, 3·927 feet; 18-inch drains, 4·712 feet; but inasmuch as the stream of drainage from a house of any size will never fill the whole area of even the smallest of these drains, the actual frictional area varies with the quantity of water passing through them.

What is the frictional area of the tubular drain you provide for a house?—In a 4-inch, if full, 1·047 feet, or one-third that of a 12-inch drain.

Supposing you were to drain from the back instead of the front, what difference would it make in the length of the house-drains?—It varies; but the average of many blocks in different localities may be stated in round numbers to be by front drainage *more than twice* the length of drain that is required by back drainage; in some cases it is three times.

Then if the frictional area of a 12-inch brick barrel drain is three times that of a 4-inch pipe, and the length is double, the total frictional area of the one must be very greatly in excess of the other?—About six times in the case supposed.

Would it not be only in case of difficulties as to property that you would drain from the front instead of the back?—Only in such cases. For instance, in the Bermondsey block there are 21 houses which must be drained separately, as the mill-stream is

immediately under and at the back of them; but, excluding these, there is but one house in a hundred through which a drain would need to be laid.

Is there the same disproportion in the size of the main sewers formerly made and those you have laid and recommended in different places?—There is.

What are the sectional areas of the main lines you have proposed and those which exist in similar streets?—The sectional area of the 12-inch main pipes is ·7854 foot; of the 15-inch, ·98175; the area of a very common size of sewer in similar streets (a sewer 5 feet high by 3 feet wide, semicircular top and bottom) is 13·07, or from 13 to 17 times the sectional area of the pipe-sewers.

Supposing the portion of Bermondsey formerly referred to were to have complete house-drainage as well as main-drainage on the plan which was formerly recognised, what would be the proportional frictional area?—Probably four or six times that of the system proposed.

And a proportional excess of water to keep the drains clear?—Yes, more.

What the difference of cost?—This is difficult to ascertain precisely, but the averages of several blocks, carefully calculated, are from six to ten times that of the tubular back drainage.

What is the actual amount of deposit in the cesspools and such sewers as there are in the district?—There are in 648 cesspools, about 30,000 cubic feet of soil, besides that in the sewers, which is very great, but constantly varying.

What difference of fall in the house-drains may there be by back and front drainage?—Never less than double in one case of the fall in the other, and generally much more.

What advantage in point of fall in a flat district like the one in question does the use of tubular sewers give you over the main lines of brick sewers?—In the one case a fall of from 9 to 10 feet has been obtained in about half a mile, whereas with brick sewers this would have been reduced to 5 or 6.

Suppose that it had been required to keep such drains and sewers in good action under the former plan of drainage, by what amount of water or arrangement of water could it have been effected?—I do not see any mode of keeping clean by any self-acting process such large sizes of drains and sewers, especially in a flat district.

If the house-drains keep quite clear, the junctions, *à priori*, will keep themselves clear?—Yes. A very important point to be attended to in laying out drainage is to unite the streams and concentrate their flow as much as possible.

Then, as far as house-drains are concerned, can you contemplate the want of any additional supplies of water to keep them clean?—With a complete tubular system of drainage, I believe

the present supply, properly delivered and distributed, to be sufficient for drainage purposes.

According to all your experience, any system of house-drains, union branches, or trunk sewers, that collects the deposit, is faulty in construction?—Yes; the processes of flushing or cleansing and ventilation are the necessary attendants only of a faulty system of drainage.

At present there is constantly a large amount of evaporating surface of decomposing refuse in the block before referred to?—There is. Many of the cesspools are close to, and immediately under, the houses. Some of the houses are built over the filthy tidal stream, and others close to stagnant ditches of the most offensive character.

What would be the expense per house of water supply, drainage, and subsoil drainage?—These, including a dust-bin to each house, and new closets where required, average 6*l.* 15*s.* per house; to pay off the principal and interest of which in 30 years would require 8*s.* per annum, or 1¾*d.* per week.

It is presumed that you give your estimates at such prices as you believe the contracts might now be obtained for?—I have in everything, both for labour and materials, allowed the present prices given for small works, and would undertake to get twenty respectable men of capital to undertake the execution of the works in the most complete manner for the estimated cost, and that without competition.

You stated a saving in length by back drainage, apart from its other advantages, to be at least one-half: what would be the saving of supplying water *de novo* at the back?—The saving in length would be about the same, and the cost of laying the pipes from the front would, on an average, be fully double the cost required to take them at the back; in many cases more.

Supposing the water to be delivered cool, would there not be less decomposition in the matter carried away?—There would; but with a perfect system of drainage there would be no time given for the process of decomposition to take place, at least upon the premises.

Since the plans have been carried out at the cloisters of Westminster, is it not stated that there have been no smells from the drains?—Such was the result of my examination made from house to house; and also that fever, which had previously prevailed, had ceased.

In respect to the distribution of water by service-pipes into houses, we showed, that when properly executed, and at rates practicable where the work is done on a large scale, it would be in reduction of existing charges, and that it was a fallacy to suppose that

the delivery of water in fountains, or stand pipes, or in any mode that imposes the labour of carrying it into houses, or upper rooms inhabited by the poorer classes, was a gratis, or even a cheap delivery. So the cost of a proper distribution of the return apparatus, or house drains, would be in reduction of the existing charges for carrying away the soil water, assuming that it must be carried away in any case.

It should be borne in mind that the plan of which the estimates are given for the sanitary improvement of Bermondsey, comprehends works for the total abolition of all cesspools, and the universal substitution of soil-pans, or an apparatus acting on the principle of a water-closet. Messrs. Walker, W. Cubitt, and Brunel, in their Report on the drainage of the city of London, object that the "recommendation" made in the Third Sanitary Report upon Westminster, "to remove and abolish all cesspools is one which, as "applicable to all present houses, we believe to be impracticable without enormous expense, and an extent "of interference with private property that would hardly "be submitted to, and at the same time, we believe, "that such a general disturbance of the substances to "be removed would be unnecessary and often highly "dangerous."

In respect to this declaration of these eminent engineers that such a general disturbance of the substances to be removed would be unnecessary, we may refer to the First Report of the Health of Towns Commissioners, signed, in 1844, by one of the reporters, Mr. William Cubitt, which says, in approval of the testimony of the medical witnesses, "The report has brought before us "facts in support of their strongly urged and unanimous opinion, that no population can be healthy "which lives amid cesspools, or upon a soil permeated "by decomposing animal or vegetable refuse, giving "off impurities to the air into their houses and into "the streets. They state the necessity of preventing "all accumulations of stagnant refuse in or near houses, "and of substituting a system of house-drainage and

"cleansing, aided by the introduction of better supplies "of water into the houses."

In respect to the impracticability of the removal of such substances, and to their disturbance being often highly dangerous, we may refer to the Third Sanitary Report for instances of the removal of such refuse with perfect safety—an immediate reduction of deleterious emanations—and so little offensiveness, that the inhabitants were, at the time, unaware of what was doing; while, in respect to the expense, we have to state our belief that the estimates given by Mr. Grant are, as he states, high maximum estimates. They include a charge imposed by the Vauxhall Company of a large tank, or reservoir, holding 3,000 cubic feet of water, costing 850*l.*, and putting each house to an expense of 13*d.* for this outlay, which is wholly unnecessary and even injurious. The rate of 1¾*d.* per week would be in reduction of the existing charges for the cesspool privy, which requires an average expenditure of 1*l.* per annum, or 4*d.* per week, for emptying and cleansing in the rare cases where it is cleansed or attended to.

It has been reported to us that the houses within the jurisdiction reported upon by these engineers do not differ materially in their condition as to drainage and number of cesspools, from two, at least, of the metropolitan parishes from which house-to-house returns have been obtained; and the engineering witnesses, who have given their special attention to the subject, affirm that upon the improved system of combined works, the expense of the apparatus in substitution of cesspools would not greatly exceed one-half the expense of cleansing the cesspools, or of repairing the house drains and the water-pipes in that part of the metropolis.

These statements of the eminent engineers to whose report we have referred, as to the enormity of the expense, must have reference to the common method of executing such works separately. It would be scarcely practicable for each tenant to execute sepa-

rately a system of back drainage; but, if he did, the immediate outlay would probably be doubled. Tables comparing the old rates of charge on the plan of separate house drainage with the expense of executing combined works have been already cited from the evidence of Mr. Lovick, and from the details of the comparative expense of combined works given in the evidence of Mr. Gotto, it has been seen that by the combination of works, and their execution under a common contract, a reduction of two-thirds of the current rates of immediate outlay would be practicable. The wide differences between estimates and actual outlays in the expenditure by trading Companies, and the extravagance made manifest upon revisions of the works, have excited natural apprehensions of enormous charges, but when the nature of the works and services contemplated are fairly explained to the parties interested, they are frequently perceived to be beneficial improvements of property, and as such promoted, especially when the principle of distributed charges is made known and understood. Mr. Grant was asked on this topic—

Does it appear to you that the water can be carried into the premises of the poorer description of tenements, or indeed of any class, by service pipes on the constant system of supply, and carried away from them by waste or drain pipes, if the work is to be dependent on the separate efforts of individual householders, or by requiring immediate outlays, or by any other system than by common contracts and repayment by annual instalments of principal and interest over periods of time?—It does not; the most stringent legislative enactment would never effect these improvements if the cost were to be paid in one sum. It would, in many cases, be most unjust; but it is, in the majority, a simple impossibility.

From your interviews with owners and occupiers, do you doubt the practicability of carrying out improved works of water supply drainage, and cleansing by means of distributive charges?—I do not; so far from its being impracticable, and considered so by owners or occupiers of houses, one instance will suffice to show. At the present time I am in communication with two parties in the district, large proprietors of house property, who are anxious to carry out works of improved drainage, but who will not undertake them if they are to pay down the cost of these works in one

sum; but, if the charges are distributed over a period of years, they would at once, and cheerfully, carry them out.

Objections to the abolition of cesspools are frequently urged on the presumption that the lowest class of occupiers are so degraded as to be unfitted for the use of the appliances of cleanliness and health. But the proper usage of them by the poorer Irish, by colliers in northern districts, and by the occupiers of mews in London, has furnished a complete answer to that objection.

We have received with very great satisfaction evidence of persons of the poorest classes in the worst conditioned districts, as in St. Giles and Whitchapel, having subscribed a penny and two-pence per week each to keep those places clean, sums which would quite suffice as contributions to a local rate from each occupant of a separate tenement, to ensure under a proper local administration the efficient performance of complete cleansing service. Objections are made to the house distributory apparatus being comprehended within the matters provided for by a general local rate, and it is urged against the system of constant supply, that it must necessitate intrusion upon private premises. If owners chose either to pay higher rates, or to dispense with the improved service, not for occupiers but for themselves, such an objection, sincerely raised, might be allowed to prevail. But the objection has hitherto in provincial towns been traced to the fact, that by the change of system from the intermittent to the constant supply by service-pipes provided under general rates, an end would be put to the intrusions of plumbers and bricklayers, which are followed by heavy bills. These bills in some of the districts examined, as in Westminster for example, for the repairs of defective house-drains alone, have amounted to 15*s.* per annum on an average of years, or to nearly double the annual rate at which, as we have seen, a combined apparatus, for the distribution of pure water, and for the immediate removal of soil water, may be laid down and maintained in good action by contract for a term

of years. By the system of combined works for back-water supply, and drainage, the derangements of apparatus and the intrusions, whether of workmen or officers, are reduced in number in proportion to the reduced lengths and simplification of the apparatus, and confined to the back premises. If such works were executed and maintained by each separate occupier, in cases of derangement of the branch main water-pipe, or branch drain-pipe, the private individual would have to obtain permission for a workman to go upon the premises of neighbours, who are apt to suspect that the object is private or personal, and so create obstructions rather than offer facilities. With a public officer whose duties and service are known to be common, it is proved by analogous experience that the case is widely different.

The character of the arrangements contemplated for the most economical relief of the evils and inconveniences under consideration, and of the objections to such arrangements, is set forth in the following portions of evidence. In relation to the Bermondsey district, Mr. Grant was asked—

Do you not consider it equally desirable, for the sake of the tenant as well as for the care of the general apparatus, that the service-pipes should be under one and the same inspection?—I do. The chief obstacle, I believe, to the water companies giving a constant supply of water is, that at present there is no security for the soundness of the supply-pipes and water-cocks; and the waste consequent upon this obliges them to shut off one part of the district whilst they are supplying another.

Would it be practicable not only to get this done, but also to get it kept in order for a certain number of years?—Perfectly practicable.

Would it not be practicable to have the main drains and water-pipes looked after by the same person who superintended the water?—It would.

Will you look to this examination of Mr. Mylne?—

[Extract from the Examination of *W. C. Mylne,* Esq., C.E.]

Were you consulted as an engineer on a plan for supplying Paris with water?—Yes, I was, in 1817 and in 1823: I am still engaged upon that subject.

In the plan you have proposed, did it not form a part that the tenants' communication-pipes should be provided and laid down

by the Company as an essential part of the works of distribution?—Yes, I considered it the most desirable that it should do so.

Will you state the advantages to the tenant or the public that were proposed from that part of the plans over the common method, leaving every uninformed occupier or owner to the necessity of employing a separate plumber to complete as he might that part of the general machinery?—In the first place, it would effect a considerable saving of capital; in the next place, it would be done on principle and in a superior manner. The trading plumber has no motive to carry out improvements, two lengths of pipe may be put where one would serve. As an example of the improvement proposed to be introduced in detail, I had intended to introduce lead pipes, with screw-joints, similar to those used in wrought-iron pipes. The cost of these joints was not above 1*d.*; they would have superseded completely the plumber's joint, and neither the plumber nor his irons, fire, ladle, nor labour were necessary, and an expense of 1*s.* 6*d.* per joint was saved. In various respects we should have economised the machinery for distribution.

This portion of the machinery being laid down by the Company, was it proposed to charge at once the expense of this outlay upon the owners or occupiers, or to charge for it a rental?—It was proposed to charge interest on the extra amount of outlay as a rental.

Then these tenants' communication-pipes would have been under the same general care as the mains or iron pipes of distribution?—Yes, that was my view; and my opinion has always been that, as public traders, that which is best for the public customer is ultimately the best for the Company by whom they are supplied.

What would be the extent of probable advantage to the public in respect to the saving of repairs?—Very great: one public officer would have been appointed to attend to the laying on of all houses, as also to all the repairs. Under ordinary circumstances, when an accident occurs within or without the building, the tenant has to think how it will be repaired, and has to consider how he is to pay for it, and who is to be sent for; the plumber, when he arrives, makes his repairs in his own way, which is without reference to any general system. Two-thirds of the labour, on the occurrence of any accident, is in the journeys, which would be rendered unnecessary under a general system, by which, on such an occurrence, the inconvenience may be remedied at once. The advantage of having the tenants' communication-pipes placed under one general system would have been, that they would have been so laid down at first as to have avoided many of the incidental injuries which they are liable to from frost and accidental circumstances, as well as being placed where they could readily be repaired.

In the case of a Company undertaking to lay down these pipes,

would not the repair of them form part of the general charge, and be added to the rent?—Yes; frequently an accident occurs towards the end of the tenant's term of occupation in the premises, and the cost of repairing it may be equal to his quarter's rent. Being a tenant at will, or near the termination of his lease, he says, "I may be turned out shortly; it is not worth my while to undertake it;" and it is left undone if within his premises.

Increased dilapidation must be the consequence?—Of course: that naturally results.

In that plan, then, you assumed as a principle that the tenants must be relieved of the immediate outlay, and the expenses be spread over a period and collected as a rent?—Yes, certainly. This was the more necessary at Paris, where the dwellings are extensively occupied in flats (as at Edinburgh and Glasgow, and in several other towns) as distinct tenements. Each flat would be held for various periods, some of the nature of tenancies at will, some of them of the nature of leasehold, and under every description of interest and period of occupation. Of course, the parties having short intervals would not undertake the immediate expense of the outlay for the permanent improvement, nor would the persons in the lower apartments pay for the repairs in any lower part of the building necessary for the supply of any upper apartment.

Did the plan of comprehending the tenants' communication-pipes and the whole machinery under one general system offer any advantages in respect to economy and efficiency in laying down the iron pipes?—In a new town there would often be much public economy in laying pipes on both sides instead of in the centre of the streets; there would be the saving of lead pipes, the saving of repairs to these lead pipes, the avoidance of the inconvenience and expense of breaking up the roads for that purpose, the saving of the inconvenience to the tenants in the event of frosts, from there being less of their smaller pipes exposed. In a street of 60 feet wide the saving of lead pipe would be about 20 feet in each tenant; that is, if the street is built upon each side there would be 40 feet of leaden pipe saved in a house frontage of (say) 20 feet; therefore 20 feet of iron extra would avoid the use of 40 feet of lead.

In carrying the water up the higher houses, would you not have introduced iron pipes?—We should have introduced iron wherever we could. At that time, when lead was very dear, I contemplated the use of tinned copper pipes.

With regard to the objection which has been made to back-drainage, that; in case of stoppages in the house-drains, one tenant suffering annoyance is at the mercy of another on whose premises the obstacle may exist, although it may not inconvenience the latter, do you believe it possible to avoid this difficulty?—Yes; if

the Commissioners of Sewers took entire control over house-drains as well as mains, I have no doubt they would find respectable persons who would contract to keep in working order the house-drains of a district for 6*d.* per house per annum.

In what proportion of cases in these other blocks did you find it necessary to carry water distributory apparatus and drains through the houses?—In one case of 51 houses, another of 226 houses, and a third of 270, there was not one house in which the water-pipes or drains had to be carried through the house.

Having displayed as far as we are able, the nature of the information we have received upon the improvements and economies practicable in combined works of water supply and drainage, as respects districts or blocks of houses—having shown how largely the power of water for the removal of refuse is increased by proper adaptation of the drains, or return apparatus, in form, size, inclination,and direction—having shown that with the present defective construction of drains and sewers enormous additional supplies of water would be requisite to keep them partially clear of noxious deposits—having given the evidence afforded by the results of well-considered and numerous trial works in proof of the conclusion, that by due attention house and branch-drains, or sewers, may be kept clear of deposit without any additional application of water supplies for that purpose, and that the necessity of intermittent flushings arises only from wholly erroneous systems of works:—there yet remained for examination the question whether the same system was applicable to those trunk lines of drainage or main outfalls, which are below high-water mark.

When the officers whose labours have been directed to the arrangement and observation of the working of improved apparatus, or the clearance of particular blocks of buildings from decomposing refuse, are questioned as to the practicability of the entire clearance of the whole of the existing area, they state the present difficulty with reference to the main outfall. Thus Mr. Lovick:—

On the whole, then, it appears from these experiments to be

practicable to have all the house refuse of the metropolis constantly removed at a rate of not less than three miles per hour?—Yes, with similar inclinations, and under like conditions; but with many of the present outlets this, of course, is not possible.

The outlets here referred to are the large main lines of sewer which are on a dead flat, or nearly so, and that flat below high-water mark, which is the case with a large proportion of Westminster, and the part of the metropolis on the south side of the Thames.

It will have been perceived that accumulations in the house-drains and the smaller branch drains are occasioned by defects in the form of their channels, by which friction is increased, and flow retarded, while, by the retardation of the flow deposit is occasioned. In districts situated as those above referred to, the retardation and deposit are occasioned by want of fall.

The present practice is to pond up the soil water by sluice-gates, until it can be discharged at low-water: but the discharge usually does not clear away the whole of the deposit, which must be removed by flushing or mechanical means. The course of operations in such districts is thus described in the examination of Mr. Grant:—

You have doubtless observed cases where water carrying soil or detritus in suspension down proper inclinations was arrested by the closing of the outfall, as in the case of the old Surrey Commission sewers, which are below high-water mark during high tides?—This is an inevitable and universal consequence in the Surrey and Kent or any similarly situated district drained on the intermittent system.

Such water when so arrested of course deposits the matter in suspension?—It does.

Now, when the surface sewer-water so arrested and detained during high-water (upon the intermittent system of drainage in Surrey) is discharged by the opening of the sluices at low water, does it lift and remove all the matter so deposited?—No: only that which is held in suspension.

The surface sewage-water is then merely decanted off by the opening of the sluices?—Exactly so. The grosser matter has to be removed either by hand labour alone, or in combination with large bodies of water flushed out.

What is the nature of the inclinations of the present main lines of sewer in the Surrey and Kent district?—In many cases they

are on a dead level for considerable lengths. An inclination of about 3 feet per mile may be taken as an average on the main lines. The fall is so trifling that the flushing-men are in the habit of turning the water in either direction in some of the sewers.

Of course such inclinations are quite inconsistent with a proper discharge of the sewage?—They are; even if the outlets were constantly open the sewage would not pass off with sufficient speed to prevent deposit.

What upon this intermittent system of drainage would be the additional quantity of water required to raise and carry away all the matter deposited during the interruption of the first flow from the house-drains, and from the branch pipe-sewers which drain blocks of houses?—No additional quantity has been found to do so by any natural or self-acting process. More or less manual labour, according to the inclinations and other circumstances, has to be employed in conjunction with the force of water, to keep such sewers at all in working order.

What is the cost of flushing the old system of sewers?—This varies very much in different districts, being highest in the Surrey and Kent district. As far as I can approximately ascertain it, it amounts to about 2*s*. 3*d*. to 2*s*. 6*d*. per house per annum in the Surrey and Kent district, that is, including wages and works necessary for such purposes. This, however, would be most materially increased if the same system of brick sewers were extended into every street. The many houses which do not communicate with the present sewers reduce the average cost of flushing per house for the smaller number which do communicate.

What are the expenses other than wages?—The cost of flushing-gates, penstocks, side-entrances, ventilating gratings, and the cost of digging down to and breaking holes into the sewers at frequent intervals, where there are no side-entrances or casting-holes, and making good such breaches.

Were not attempts made to ventilate one of the sewers last summer, and what was the result?—Several attempts have been made, the last by means of the steam-jet, and also by passing the air of the sewer through a furnace into a factory chimney. The steam-jet will ventilate a certain length of sewer, if it be ever so foul; and, for a special purpose, might be a useful means of preventing danger. By the factory chimney there was a constant and sensible draught kept up, which would, I believe, justify the cost of making a connection with such of the present main sewers as were near tall chimneys, at least as a supplementary means of ventilation.

Have you provided means of ventilation for the tubular systems laid out by you?—No; I believe ventilation, flushing, and additional supplies of water to be necessary only for an imperfect system of drainage, and that the cost of them would go far towards executing a complete and perfect system of drainage.

Mr. Lovick, the officer in charge of the flushing:—

You of course have had to flush the sewers in the Surrey and Kent district, and have observed there the effect of the intermittent discharges of the drainage matters which are backed up and kept within the district during high-water? In the discharge of the sewers there, is not the sewage matter decanted off, leaving the matter deposited, and what are its effects?—Yes. From the drainage matter in this district being locked in for many hours in each day, a very large proportion is deposited, and, when the outlets become free, then the liquid portion, with but a slight amount of the solid matter, is decanted off, or flows into the Thames. And as the reservoir sewers become full, the foul gas is expelled from them through every opening into the public thoroughfares and into the private houses. And the generation of foul gas is quickened by the stagnation of the drainage, being continully formed and continually expelled by the progressive accumulation, so that not only are mechanical difficulties created, but health is jeopardised by this arrest of the flow.

Have you estimated what would be the quantity of water required to flush away this matter?—It would be difficult to do so, as (owing to many of the collateral and parts of main sewers being below their outlets; to irregularities in them; and to the unavoidable deficiency of fall in even the best constructed lines, from much of the district being below high-water; and from the drainage being locked in by the tide about two-thirds of the time) it is impossible to remove much of the deposit from many of the lines. The present quantity of water, with the immense volume now procured from the Thames through the various sluices, probably at least from eight to ten times greater than the ordinary sewage-flow, is wholly inadequate to keep even many of the better class of the low-level sewers clean.

The clearance of the house and branch drains of the upper district must add to the accumulations and aggravate the existing evils of the lower district, so long as the sewer water is ponded up there, by closing the outfalls. The evaporating surface of sewer water in the house and branch drains of the upper levels will be reduced by the proper adjustment of the sizes of the channels, and during the daytime whilst there is a discharge of soil water through the branch pipes. The observation of the existing examples warrants the expectation, that the run of that water would frequently be sufficient to carry with it a down draft of air, and thus protect houses from noxious gases; but at night, when there will be little or no discharge

of sewage, and at other times, the emanations from the accumulated deposit, and the surface of the stagnant sewer reservoir, will ascend the branch tubular drains, and through them pass into the streets and dwellings on the upper levels. At times, and in certain barometrical conditions, the ascent of effluvia from this description of deposit in the lower districts, is peculiarly powerful and noxious.

For the effectual removal from the lower levels of all the increased amount of soil discharged upon them by the improvement of the drainage of the upper levels, such new and expensive cuttings as have been proposed for the better discharge by intermittent flushings of the present accumulations of deposit would still require increased volumes of water. The expense of these works, and the other expenses attendant on the practice of clearing these lower districts of deposits by intermittent flushing, though large, would be a minor object. The continued pollution of the river by the discharges of sewer water, though it is a serious evil, is yet far less than the evil of maintaining soil-water reservoirs, and accumulations of decomposing deposit, amidst or under the site of habitations.

The whole practice of flushing is, however, maintained in ignorance of actual hydraulic facts and in opposition to the results of extensive experiments; and is condemned as unnecessary by our engineering inspectors and the most competent practical witnesses.

The arrangement upon which our inspectors agree, as effectual for the prevention of all deposit, is to continue the proper inclination of the main sewers from these lower levels, so as to keep up the uniform rate of flow, and to discharge the contents by pumping at the outfall, and thence convey it either in the direction of any demand there may be for it as a manure, or, until the land is fitted for its reception to discharge it low down the river, at a distance whence it could not be brought back amongst habitations by the return tide.

The prevention, by the system of constant supply, of a discharge of waste water equal to an extra rain-

fall upon the lower districts, would, under a system of combined works, proportionately reduce the expense of pumping, and facilitate the discharge of the soil water to a sufficient distance at a less expensive rate than hitherto contemplated. Our engineering inspectors agree in estimates which we shall subsequently submit, showing that the expense of sufficient pumping would be greatly below the expense of sufficient flushing for the relief of the lower districts.

By ascertaining the actual rates of the consumption of water, and approximating more closely to the probable consumption under an improved system, the data and the conditions of the questions are greatly altered and rendered more certain.

By extended observations as to the inclinations at which existing sewers are kept clear of deposit by the ordinary run of sewer water, data have been obtained for determining with certainty the inclinations at which deposits may be prevented by pumping.

By extended trial works it has been proved, that by improvements in the manufacture of earthenware pipes, by rendering them more accurate in form and smooth in surface, the rate of flow of the same quantities of water at the same inclinations, as compared with the flow in sewers of the ordinary construction, may be accelerated from one-fourth to one-third.

By a better observation of the quantities of pipe water required to be pumped, and of the rain-fall, a better estimate may be made of the expense of pumping out the gross quantity of water and conveying it away.

In some of the plans of engineers, and in the statements of Commissioners of Sewers, when referring to the discharge of sewer water by the intermittent system when the tide is down, they speak of it as a natural method, and, as such, preferable to the discharge by any system of pumping, which they designate as "artificial" and therefore, to be avoided. We apprehend, however, that there is scarcely anything natural about the case; the banking out the river, the erection of tidal gates, and the arrangements for intermittent drainage and

flushing, all being artificial. Large areas in this country and in Europe are now profitably drained by artificial means for agricultural use alone, which must if left to "a natural method" be permanently under water. That which is done for large and wide districts of bare land, many feet below the sea, may be effected with singular advantages on much smaller areas crowded with human habitations, and worth, comparing area with area, more than a thousand times as much in money value alone, and infinitely more when the stakes of health and life are considered. The fact appears to be unknown, or unattended to, that when, as in the lower districts of Westminster, the flow of the sewer water is arrested, and the matter in suspension thereby deposited, it requires a far larger quantity and power of water to lift and again get it in motion for removal than would continue it in motion at the same inclinations. As the extra quantity of water required in such cases for flushing on the intermittent system of drainage must, when there is no rain-fall, or when the rain-fall is insufficient or irregular, be artificially obtained; pumping at the lower level, as proposed in cases of insufficient fall, can only be avoided by pumping a greater quantity at the higher level.

The question, then, is admitted by the most practical officers to be one of greater or less pumping at one end or other of the apparatus. In one particular instance, the additional quantity of water required for flushing is proposed to be derived from the river by a deep cutting, from which it is estimated that the trunk main may be flushed; but our inspectors are agreed, that the expense of such a work, apart from the sanitary objections to the retention of refuse, under any intermittent system, must be greater than the expense of preventing the accumulation by a constant flow obtained by pumping.

Mr. Lovick was asked in respect to the quantity of deposit now removed by partial flushings:—

How many loads of deposit have been removed in any one week in the Surrey and Kent district? What is the total quantity of deposit removed in any one week in the whole of the metropolitan district?—It is difficult, if not impossible, to ascertain correctly the quantity removed, owing to the variety of forms of sewers and

the ever-varying forms assumed by the deposit from the action of varying volumes of water; but I have had observations made on the rate of accumulation, from which I have been enabled roughly to approximate it. In one week, in the Surrey and Kent district, about 1,000 yards were removed. In one week, in the whole of the Metropolitan districts, including the Surrey and Kent district, between 4,000 and 5,000 yards were removed; but in portions of the districts these operations were not in progress.

In respect to the additional expense of power incurred, and force of water required by the interruption of the continuous flow, his evidence is in accordance with that of Mr. Grant; but we cite it for its important practical bearing:—

But this is with a continuous fair fall; now, supposing the continuity of the fall to be interrupted by the outlet being below high-water mark, of course the matter which before was carried in suspension would be deposited?—As the power to remove matter in suspension is in proportion to the volume of water, and to the velocity with which it moves, and as this velocity increases with the increased inclination, any interruption of the fall or decrease of inclination must be attended with a proportionate loss of power, and this becomes progressive in sewers situate in districts below high-water mark, where the outlets are affected by the tide, so that where sewers pass through a district of this kind from a higher level the matter held in suspension in the flow in the higher parts is deposited as it is brought down into the lower level.

Is it not found that this detritus becomes indurated, and requires a greater force of water to remove it than that necessary to keep it in suspension?—Yes. The detritus will become so indurated as to require a very considerable force of water, and even manual labour aided by proper implements, to remove it, so that the force of water necessary to keep such matter in suspension bears but a slight proportion to the force requisite for its removal when it has once become indurated.

In places which are below high-water mark for how many hours is the flow arrested?—This will vary in places. In some districts the flow would, on the average, be arrested for two-thirds of the day, or for 8 hours during the daily tides, or for 16 hours, taking the tides throughout the 24 hours.

Then, in consequence of the arrest of the discharge in these low-lying districts, a much larger volume of water is requisite to lift and remove the matter so deposited?—Yes. The quantity of water necessary to keep matter in suspension in lines laid at a due inclination, and where the discharge is continuous, bears but a slight proportion to the enormous volume required to lift and remove the same matter after it has been deposited.

Supposing the additional quantity of water necessary to remove

the deposited and indurated matter is to be sent in by pumping, would it not be a greater economy of pumping power to lift the water from a lower artificial level, in order to preserve the continuity of the discharge? With a proper tubular system of house-drains and sewers, would it not be a large economy of power to pump?—If the supply of water now used for the prevention of accumulations of deposit in this district had to be pumped into the district, and if, as the question implies, an artificial outfall was to be provided, so as to ensure a proper tubular system of house-drains and sewers, or a system constantly discharging, the power requisite to pump the supply of water now used into the district for the prevention of the accumulations of deposit from the ordinary drainage in the present sewers would much exceed the power requisite to pump up the ordinary drainage from such artificial outfalls, much more would be the excess of power required were *additional* supplies of water pumped in for sewer-cleansing purposes.

The proportion of soluble and insoluble matter in sewer water is usually less than one to two hundred and fifty times its volume; night soil is pumped with two or three times its volume of water. In the Potteries they pump clay in suspension with only twice its weight of water; some engines have been worked for long periods pumping liquid clay, with one of sand in suspension in six and seven of water. Bricks have accidentally got into water mains and have been pumped to considerable elevations. Mr. Quick, the engineer of the Vauxhall and Grand Junction Water-works, who has had great experience in pumping operations on a large scale, was consulted at the commencement of the sanitary inquiry, upon the means of relieving the Surrey and other low-lying districts from the sewage water; and he is clearly of opinion that there is nothing in the nature of soil water, holding in suspension the ordinary matter contained in it, to prevent its being pumped out, through closed pipes, to any elevation, with the same certainty and regularity that the pipe water is now pumped in; and that there is no more special need for large reservoirs, to meet the case of accidents, in the one mode of working than in the other.

Since therefore the smallest channels of conveyance, the house-drains, which have, in proportion to the flow

of water, the most friction, and the branch drains, which have less friction, are kept free from deposit without special supplies of water, when due adaptations in respect to form, size, and inclination have been preserved, we may be quite certain that the large mains having the least friction, will, when the like inclinations are maintained, be kept as completely clear by the same runs of water.

It consequently follows that additional supplies of water are unnecessary for flushing sewers, even in the districts below high-water levels, and that under a practicable system of combined works, with proper adaptations for the discharge of waste water, there would be no stagnant deposit or decomposing refuse under any part of the site of the metropolis.

Whilst in the first part of our examination of the state and management of existing works we have displayed the consequences attendant on a separation of the control over water mains from that over house service, and shown that the pollution of the water in cisterns with numerous other domestic inconveniences and greatly increased expense have been the result; —the second part of the examination has exhibited the large evils arising from a still further separation of the machinery of water supply from that for water-removal—as the flooding of the lower districts with waste water, the consequent creation of damp, the dilapidation of buildings, and the conversion of the greater portion of the existing sewers and drains into extended cesspools,—evils which practically could not fail to arise from carrying on one set of operations so closely and inseparably related without the slightest reference to the other. In the several engineering schemes which we have examined, it is expressly proposed to give additional supplies of water for the purpose of flushing. Such propositions involve the recognition and maintenance of works which accumulate deposit and generate and diffuse the gases of decomposition.

The result to be obtained by a proper combination

of works, in the immediate and rapid removal of refuse, and the prevention of its accumulation under or near dwellings, is even now so little understood, while it is of so much practical importance, that it is necessary still further to illustrate this part of the subject, by adverting to the futility of the expedients resorted to for the correction of the evils arising from disconnected and inefficient works.

The public having required protection from noxious gases issuing from decomposing refuse in street sewers and drains in immediate connection with houses, recourse has hitherto been had by engineers and surveyors to flap-traps, to prevent the escape of effluvia. These flaps, for "gully shoots," or the openings from sewers into streets, have varied from eight pounds to half a hundred, and even one hundred weight; and for house-drains from two pounds to twelve. But the rates of discharge through these channels had not been considered, nor the fact that the heavier flap would, when water was constantly discharged in mere driblets, weigh down and detain substances in suspension. This form of apparatus was adopted without any previous trial, and has been continued in use without sufficient observation until the recent investigations, when it was found that it did not effect the objects intended, but that it commonly aggravated the existing evil by the collection of filth in the lower part of the trap, and the detention and accumulation of light floating substances in the sewers. The matter thus accumulated decomposing, the general experience in the city and other places was that more offensive smells arose from the sewer cesspools formed by the traps, than from the sewers themselves. To whatever extent the traps placed in the gully-shoots acted in obstructing the discharge of the products of decomposition into streets, they increased the amount and rapidity of the discharge through untrapped house-drains into houses.

It was also found that the trapping of main sewers frequently favoured decomposition, and prevented

the transmission of the gases generated in them, so that the men employed to cleanse them were constantly placed in imminent danger. It was further found that when gases are evolved in considerable quantities from decomposing refuse, whether in sewers or house drains, they force their way through water in bell-traps, through syphon-traps, and through every other description of trap. Loud demands have been made that long lines of open ditches and sewers containing stagnant deposit should be arched over, but this measure, as now executed, though it may mask, actually aggravates the evil, at an expense often double that which, with a proper combination of works, would suffice for its prevention.

Openings have been made from the sewers communicating with the open air in the centre of the streets. An iron-grating may be seen covering these untrapped vents, which can only serve to let out the foul air in the centre of the roadway instead of in the channel through the gulley-grate, as heretofore. The atmosphere of the town is contaminated no less by the alteration.

The system of trapping having failed, other plans have been proposed, with a view to the ventilation of large sewers. The expedient of erecting chimney-shafts with furnaces to draw out the foul gases has been tried, for example, at Paris and Antwerp. Sewers have been partially ventilated by this means, but some of these gases being heavier than atmospheric air have again descended, and spread offensive odours over wide districts. At Antwerp it has been observed, that though in certain states of the weather no offensive odour could be perceived, yet whenever any fog hung over the city the diffusion of noxious gases was rendered disagreeably sensible. In London, the steam-jet has been tried, and like the chimney-shaft, it has been found partially to discharge the gases from sewers, but by frequent renewal of the air in contact with refuse in rapid decay, it is doubtful whether the result of this experiment was not a far more quick

and copious diffusion of foul and dangerous gases, which, though drawn from the sewer and discharged into the surrounding atmosphere, were not changed to a condition of salubrity. Upon the whole, these operations have not realized their promises.

Another class of remedies has been suggested, which it was proposed to bring into use on a large scale, namely, chemical "disinfectants," as they are termed, but more properly "deodorizers;" for though they undoubtedly destroy the most offensive odours, arising from the putrefaction and decay of vegetable and animal matters, yet there is no sufficient evidence that they decompose and destroy the noxious gases themselves. (*See* Appendix, Second Sanitary Report.)

On a review of the whole evidence, it appears that there is no true remedy for the evils in question, but that which prevents the accumulation of refuse matter by providing for its immediate and rapid removal.

But even supposing that the several expedients of covering over the refuse, of shutting out emanations by trapping, of ventilating sewers, and of deodorizing their contents, had upon trial proved to be completely effectual, there is reason to believe that far greater expense would be entailed for works of this character than for proper works by which accumulations would be entirely prevented.

Hitherto blocks of houses in which the combination of water supply with tubular drainage has been effected have all had their outfalls in old sewers, whence some of the products of decomposition might still be derived. Nevertheless, the unanimous testimony of the residents in such houses is that immediate and apparently complete relief has been experienced. It is indeed only when the deposit accumulates and stagnates that the copious evolution of deleterious gases takes place. All the surveyors and other witnesses whose duty compels them frequently to traverse these sub-ways, concur in stating that they sustain no inconvenience whatever, and perceive scarcely any smell from running

sewer water. Nor is there apparently any evolution of putrescent gas from this source; and indeed, when substances in the incipient state of putrefaction and decay are immersed in cold running water, decomposition is immediately checked. When the run of water is concentrated in the branch tubular drains, the draft of air procured is downwards rather than upwards, and this must be so when the flow is considerable. It is confidently predicted that when the common syphon or water-traps are relieved from the pressure of such gases as are now evolved from stagnant fluid and semi-fluid matter, they will be found effectual in arresting any odours which may arise from the reduced surface of running sewer water.

Besides the instances of perceptible reductions of sickness, incidentally mentioned in evidence already cited, we have had brought under our consideration the model dwelling-houses, which afford an example of water supply, laid on with sinks and cleansing apparatus on each story. Though the whole of these arrangements are as yet confessedly imperfect, the health of the inmates has been greatly improved, and they have enjoyed an almost entire immunity from typhus and other epidemic disease which have continued to ravage the same classes of persons living in dwellings without these provisions.

The exposition we have made of the inexpensiveness of combined works is the more necessary, inasmuch as we find that although it is now some years since the excessive expense and evil of large drains were set forth in the first sanitary reports, engineers and architects of high rank in their professions present estimates for them in provincial towns, and construct them for public and private edifices. Thus we find in private investigations for the application of the Public Health Act to Newcastle-upon-Tyne and Gateshead, that a sewer has recently been made in one instance 7 feet 6 inches high by 4 feet wide, where a 12-inch pipe would have served the purpose much better; and other sewers 3 feet and 4 feet high have

been made for single streets, where a 6-inch pipe would far better attain the proper objects of the construction. In all these cases the cost of the large sewer is several times that of the pipe drains, and the latter would free themselves from refuse, whereas large sewers accumulate deposits, generate foul gases, and harbour vermin.

The late George Stephenson reported upon the drainage of Carlisle, and estimated the expense of street sewers at upwards of 70,000*l.* Upon the recent investigations of our engineering inspector, Mr. Rawlinson, it is estimated that the whole city may be far more efficiently drained for 10,000*l.* At Southampton the expense of draining the town had been put at upwards of 51,000*l.* Our engineering inspector, Mr. Ranger, calculates that, on the improved plan, it may be accomplished for 26,000*l.* A very complete plan, with some improvements, had been laid out for Reading, at an expense of 60,000*l.* Our engineering inspector, Mr. Lee, is confident that the improved drainage works, including complete house-drainage, may be executed for little more than 25,000*l.*

One common mistake, leading to excessive expense and inefficient work, in laying out the drainage of a town, is to arch over some natural stream or water-course as a main or outlet sewer, and this frequently costs as many pounds per year as the pipe-sewer necessary for the drainage of the house would cost shillings. It is a mistake in any instance to form a natural water-course into a main sewer for the following reasons: —The area drained by a brook or other natural water-course will, in general, be many times greater than the area occupied by buildings;—the flow of water will be irregular and uncertain; being the least when most required, and being in excess when it is a nuisance rather than a benefit. Secondly, the dimensions of the sewer must be capable of taking away the heaviest rainfall of the whole district, and consequently must be of dimensions much beyond the requirements of the town proper, while the expense will be in pro-

portion to the dimensions. Thirdly, the sewer must be open at both ends on account of sudden floods; sticks, stones, sand, and other similar material will be washed in from the open country, to be deposited within the sewer in dry weather. This rubbish will retard and retain the refuse from the house-drains passed into it; and in all dry seasons such a main sewer will become most foul and dangerous to health, probably requiring hand labour at a great cost to cleanse it. The natural water-courses of any district should, as much as possible, be restored to their original purity by cutting off all house-drainage; it is, we find, cheaper to construct sewers and drains entirely independent of all such means of outlet. First, because the sewers and drains can be accurately graduated to the work they have to perform at all seasons and under all circumstances;—secondly, because the refuse may best be collected, directed, and dealt with for agricultural purposes;—and thirdly, because, where it may be advantageous to pump the whole refuse, that which properly belongs to the town and the houses drained is alone lifted; and generally, because, where it becomes necessary to arch over a natural water-course through a town, such a tunnel ought not to be contaminated with sewage refuse. In general, it is better that the excess of surface rainfall only should be allowed to pass away by this means.

IV. It remains for us to consider *fourthly*, the advantages of a system of constant supply for surface-cleansing, diminution of risk from fire, and new applications of water as a source of power, for which, as a general rule, no sufficient provision is made in any of the more recent schemes.

Those whose duties have led them to visit courts and alleys in the more depressed districts, after they have been swept by the scavenger's broom, are aware that although this may remove the larger collections of filth from the pavements, it frequently spreads the ordure as a coating over the surface. Such surfaces, with the walls and basements of buildings, can

only be thoroughly cleansed by washing. The disposition of many poor inhabitants to contend for cleanliness against surrounding filth is frequently shewn in the careful washing of the doorway footsteps to their own houses. During the prevalence of cholera, we frequently recommended the use of the parish fire engines for cleansing such places, a service which they performed in the most rapid and complete manner.

Dr. Sutherland thus reports on its application:—

During the late epidemic of cholera, I had several opportunities of witnessing the beneficial effects of the water jet in cleansing filthy localities, and in flushing sewers. Sometimes the jet was attached to a fire-plug, and at others, where there was no head pressure and constant supply, the fire-engines were used.

In those narrow filthy closes, and similar close localities, which exist more or less in all large towns, it would, in my opinion, be of very little good, in a sanitary point of view, to endeavour to keep them clean by sweeping. The very process may, at times, do mischief, for at the best, it involves the smearing of the surface with unwholesome and offensive matters, so as to expose a larger evaporating area to the atmosphere. I have often found the air of these places insupportably offensive after the work of the scavenger was completed. Not unfrequently, the paving is also in a very defective state. It gets broken up in a variety of domestic processes, such as wood-splitting and the like, so that the broken surface adds materially to the local unhealthiness, by the accumulated filth which it harbours. In such cases scavengering is of no use; but it is precisely in these that surface-washing is most effectual. It cleanses everything away, and sweeps it into the nearest sewer, leaving the pavement as clean as it would have been after a thunder-shower. I have advised the use of the water jet in all cases where the supply would admit of its application, and where the defective cleansing required to be immediately and efficiently remedied; and the sanitary results have been marked in some cases, while in others, there can be no doubt that it diminished the localizing influences which tended to develop the disease.

The power of the water jet, in cleansing out drains and sewers, is greater than is generally imagined, and I have seen much benefit result from its use, for this purpose also.

The great obstacle to the application of so very efficacious a means of cleansing, I found to be the paucity of the water-supply. In no case that I know of has it been so extensive as to admit of the use of the jet as frequently as was required. The result of the experience obtained during the cholera, on my own mind, is,

that no town water-supply is worthy of the name, in which an ample allowance is not made for this, as well as for other sanitary purposes, in addition to a very liberal quantity for purely domestic use.

The trial of a jet d'eau, with a hose affixed to the water mains, was recommended to the Metropolitan Commissioners of Sewers, and a number of careful trials were made by Mr. Lovick, who gives a detailed account of them in his evidence. Similar experiments were also made by Mr. Hale. Some trials of this mode of cleansing had previously been made by Mr. Lee, one of our engineering inspectors. Mr. Lovick conducted his experiments with such jets as could be obtained from the water Companies' mains in eligible places; but the pressure was low and insufficient. Nevertheless, it appeared, that taking the extra quantity of water required, at the actual expense of pumping, the paved surfaces might be washed clean at one-half the price of the scavengers' manual labour in sweeping. Mr. Lee's trials were made at Sheffield, with the aid of a more powerful and suitable pressure, and he found that with such pressure as he obtained the cleansing might be effected in one-third the time, and at one-third the usual expense of the scavengers' labour of sweeping the surface with the broom.

The effect of this mode of cleansing in close courts and streets was found to be peculiarly grateful in hot weather. The water was first thrown up and diffused in a thin sheet, it was then applied rapidly to cleansing the surface and the side walls, as well as the pavements. Mr. Lovick states that the immediate effect of this operation was to lower the temperature, and to produce a sense of freshness, similar to that experienced after a heavy thunder-shower in hot weather. The same expedient was resorted to for cooling the yards and outer courts of hospitals, and the shower thrown on the windows of the wards afforded great relief. Mr. Lovick in his report on the trial works for cleansing courts states—

"The importance of water as an agent in the improvement and

preservation of health being in proportion to the unhealthiness, or depressed condition of districts, its application to close courts and densely populated localities, in which a low sanitary condition must obtain, is of primary importance. Having shewn the practicability of applying this system (cleansing by jets of water) to the general cleansing of the streets, my further labours have been, and are now, directed to this end.

For the purpose of ascertaining the effect produced by operations of this nature upon the atmosphere, two courts were selected: Church-passage, New Compton-street, open at both ends, with a carriage-way in the centre, and foot-way on each side; and Lloyd's-court, Crown-street, St. Giles's, a close court, with, at one entrance, a covered passage about 40 feet in length; both courts were in a very filthy condition; in Church-passage there were dead decaying cats and fish, with offal, straw, and refuse scattered over the surface; at one end an entrance to a private yard was used as a urinal; in every part there were most offensive smells.

Lloyd's court was in a somewhat similar condition, the covered entrance being used as a general urinal, presenting a disgusting appearance; the whole atmosphere of the court was loaded with highly offensive effluvia; in the covered entrance this was more particularly discernable.

The property of water, as an absorbent, was rendered strikingly apparent in the immediate and marked effects of its application, a purity and freshness remarkably contrasted to the former close and foul condition prevailing throughout. A test of this, striking and unexpected, was the change, at different periods in the relative condition of atmosphere of the courts and of the contiguous streets. In their ordinary condition, as might have been expected, the atmosphere was purer in the streets than in the courts: it was to be inferred that the cleansing would have more nearly assimilated these conditions. This was not only the case, but it was found to have effected a complete change; the atmosphere of the courts at the close of the operations, being far fresher and purer than the atmosphere of the streets. The effect produced was, in every respect, satisfactory and complete; and was the theme of conversation with the lookers-on, and with the men who conducted the operations.

The expense of these operations, including water, would be, for

Church-passage (time five minutes) .	1½*d.*
Lloyd's-court (time ten minutes) . .	3¼*d.*

Mr. Hale, another officer, gave a similar statement.

Experiment 1—*September* 20*th.*—A Court in Bedfordbury.—Temperature of court before cleansing, 69½ degrees; after

cleansing, 66 degrees. Fall of temperature produced by cleansing, 3½ degrees. Before cleansing there prevailed in the court a sense of closeness and stagnation of air, and a variety of noxious smells arising from public urinals and stagnant drainage-water evaporating from the open channels, besides the dirt on the pavement and sides of the houses. After cleansing, there was a decided change to a sense of coolness and refreshment, and the absence of all smells; and a current of air was perceived to pass through the court, produced, as it seemed to me, by the sudden depression of the temperature in the court destroying the equilibrium of the atmosphere in the neighbourhood.

Experiment 2.—LASCELLES COURT, BROAD-STREET, ST. GILES'S.—This court was pointed out to me as one of the worst in London. Before cleansing, it smelt intolerable and looked disgusting. Besides an abundance of ordinary filth arising from the exposure of refuse, the surface of the court contained heaps of human excrement, there being only one privy to the whole court, and that not in a state to be possibly used. The appearance of the inhabitants was as ill-conditioned as the wretched place they dwelt in. The cleansing operations were commenced by sprinkling the court with deodorising fluid, mixed with 20 times its volume of water, a great change from a very pungent odour to an imperceptible smell was immediately effected; after which the refuse of the court was washed away, and the pavement thoroughly cleansed by the hose and jet; and now this place, which before was in a state almost indescribable, presented an appearance of comparative comfort and respectability.

Experiment 3—*September* 25*th.*—An ordinary wide street with plenty of traffic. Here the great difference between ordinary modes of cleansing, and thorough cleansing by the hose and jet is remarkable. Water-carts and ordinary rains only create the mud which the jet entirely removes, giving to the pavement the appearance of having been as thoroughly cleansed, as the private stone steps in front of the houses. Even in a street seeming not to require any cleansing, the use of the hose and jet affords a change at once refreshing and agreeable.

Familiarity with streets of crowded traffic deadens the senses to perception of their actual condition. Strangers coming from the country frequently describe these streets as smelling of dung like a stable-yard. In paved streets of much traffic the greater proportion of the filth removed from the surface is horse-dung. Between the Quadrant in Regent-street and Oxford-street, a distance of a third of a mile, three loads on the average of dirt,

almost all horse-dung, are removed daily. On an estimate made from the working of the street-sweeping machine, in one quarter of the City of London, which includes lines of considerable traffic, the quantity of dung dropped must be upwards of 60 tons, or about 20,000 tons per annum, and this on a City district, which comprises about one-twentieth only of the covered area of the metropolis, though within that area there is the greatest proportionate amount of traffic. Though the data are extremely imperfect, it is considered that the horse-dung which falls in the streets of the whole of the metropolis cannot be less than 200,000 tons a-year. Much of this, under ordinary circumstances, dries and is pulverised, and with the common soil is carried into houses as dust, and soils clothes and furniture. The odour arising from the surface evaporation of the, streets when they are wet is chiefly from horse-dung. Susceptible persons often feel this evaporation, after partial wetting, to be highly oppressive. The surface-water discharged into sewers from the streets and roofs of houses is found to contain as much filth as the soil-water from house-drains. On this account, the proposal to separate the surface-drainage of the streets and covered spaces of urban districts from the house-drainage has been pronounced to be practically an error involving foul expense and inconvenience of two sets of drains instead of one, with reduced power of sweep for discharge. Even that efficient and economical implement, the street-sweeping machine, leaves much filth between the interstices of the stones and some on the surface, which, by the jet d'eau, may be effectually cleared away.

Slight showers only wet the mud, and on ill-paved streets occasion a considerable amount of insalubrious surface evaporation. The cleansing of a paved street, and indeed of a Macadamized surface, by a jet properly applied, and with adequate pressure, leaves the surface more clear of pools or any other kind of moisture than it is after the heaviest thunder-shower.

Dr. Arnott has long urged the consideration of the injurious effects of the excess of dust upon the public health in the metropolis.

It is (he says) scarcely conceivable that the immense quantities of granite-dust, pounded by one or two hundred thousand pairs of wheels working on Macadamized streets, should not greatly injure the public health. In houses bordering such streets or roads, it is found that, notwithstanding the practice of watering, the furniture is often covered with dust, even more than once in the day, so that writing on it with the finger becomes legible, and the lungs and air-tubes of the inhabitants, with a moist lining to detain the dust, are constantly pumping the same atmosphere. The passengers by a stage-coach in dry weather, when the wind is moving with them, so as to keep them enveloped in the cloud of dust raised by the horses' feet and the wheels of the coach, have their clothes soon saturated to whiteness with the dust, and their lungs of course are charged in a corresponding degree. A gentleman who rode only 20 miles in this way, had afterwards to cough and expectorate for 10 days to clear his chest again.

We have been unable to determine how much of the dust which penetrates book-cases, collects on all kinds of household furniture, and befouls the linen and the person in the metropolis, is composed of this road dust and how much of soot. But the compound certainly occasions clothes and linen to be dirtied at least twice as fast as in the rural districts, or in other words, subjects the population to a double expense to obtain the same amount of cleanliness.

Judging by Mr. Lovick's trial-works, the carriage-way and also the footway of the Strand might be completely washed on six days in the week, in one hour every morning, before the commencement of the traffic, at a charge of little more than fourpence per house per week: according to Mr. Lee's trials, with a more powerful jet, it might be done for less than one-half that sum. Mr. Lovick estimates that for a penny per house the thoroughfares in one quarter of the streets might be washed once a day, and in one half of the streets twice a week.

To families of the poorest class such a service as the cleansing of the courts and alleys where they reside,

(apart from the general cleanliness, procurable for the whole population of the metropolis, at so low a rate of contribution from each,) would be an economy of a great part of the present expense of the wear of clothes and of washing.

The provisions for paving, and the present state of the pavements near the dwellings of the poor, would, however, require to be amended before the proposed mode of surface cleansing could be generally adopted. A large proportion of the districts most densely peopled by the labouring classes in the metropolis are without any pavement whatever. A powerful jet, applied by the hose, would scoop out hollows in such unpaved places, and also loosen and remove the stones in those that are badly paved. On the mere score of economy in the saving effected in washing, and the wear and tear of clothes, it would be remunerative to pave properly all such places, in order to apply the mode of cleansing by the jet. The total absence of paving, or the defects of such paving as there may be in the districts inhabited by the poorer classes, is often pleaded as an objection to the application of more effectual means of cleansing. Actual local examination, alone can give a conception of the extent to which, from local maladministration, the children of the poor are crowded together, and brought up in the filth of wet and unpaved yards and courts. In the course of the communications from a deputation to us on the subject of the water supply, from the parish of St. Olave's, Southwark, one of the deputation thus described the condition of these populations: —

I am such an advocate for water, that I do not know that any outlay at all in comparison would be too expensive for the advantages which the landlord and his house would receive from it. I have had a good deal to do with houses. I have had a great deal of practice, and given a very close application to drainage, and I consider that, though there may be a great outlay, great advantages are derived in many instances. If a house is well drained the wood-work and walls keep dry; not only that, but on going into the house there is no smell, and there are many other circumstances connected with good drainage and dryness. * * * *

If I may be allowed just to give an instance, as one of the Commissioners of Pavements, I recommended the paving of the back streets and the courts and alleys as the first sanitary measure almost which should be done after the drainage. I have been a Commissioner of Paving twelve or thirteen years. Of course, as a self-elected Board, we differ a great deal upon these matters; and I have noticed that we have always taken care of the high streets; we always pave them well; and if there should be any complaint, some of the Commissioners and some of the parishioners that live in those streets come down and say it is so; but there is hardly ever found a word about the back streets, or lanes, or courts and alleys, because they are generally inhabited by the poor, particularly in those districts where there is not a leading thoroughfare to other places. That is the case in our district. The other day, along with some other Commissioners, I recommended that they ought to be paved, and they paved one. I took my clerk down with me, and we went into every house. I have not brought the account with me, but I think there are about 30 houses, and in those 30 houses I should think there were about 200 persons, all labourers, and I am sorry to say that most of them had been out of work the greatest part of the winter. Some had six children. I said, "What do you pay for this house?" "Three shillings and sixpence a-week." "Who is your landlord?" "So-and-so." "How many rooms have you?" "Three." Some of those houses had seven, eight, ten, twelve, and fourteen children in them, and the father and mother. In each of those houses they had privies running over in the yards, and actually coming right down into the houses. I think that in a district of about 25 houses, where there are, I may say, 200 children and men and women, there are 14 or 15 privies all running over. I could give you the names of the places. That is in the neighbourhood of Tooley-street. One is Brewer's-alley; it is in Vine-yard. Vine-yard is the leading place to it—Vine-yard, leading into Tooley-street, going down to one of the finest rivers in the world to be drained. Vine-yard runs from the south of Tooley-street down to the south side of the river. It is a distance of about 150 yards long, and within those 150 yards, both right and left, I should say there were 150 privies all running over in different parts of the district.

Mr. Bloyd. I would only just make one remark with reference to what my friend very ably stated in respect to the advantage of paving. I happen to be a Commissioner of Paving myself, and can bear testimony to every word he has stated. But in that district my attention was called to it as one of the guardians of St. Olave's Union. The relieving officer, in giving in his report, stated that there was a district called Jaques'-buildings, leading out of Vine-yard, continually having fever. This struck my ear as

a guardian; and on the following Thursday, on going to the Board of Pavement, I directed our street-keeper to go there. He reported, and stated that the place was very filthy; that most of the privies were overflowing, aud that there was no drainage. My friend Mr. Evans and another Commissioner or two went round; we surveyed the place, and had it paved. Our medical officer stated at the Board of Guardians that several of the houses in that district had continually fever; and when we went round, the atmosphere was so fœtid that we could scarcely breathe—it almost made one sick. The whole neighbourhood was in a state of filth and want of cleanliness. Most of the occupants of the houses are poor; their children and their sisters and mothers and wives, and so on, are employed in making sacks; and very densely populated indeed it is. But the report of the medical officer fastened upon my attention the necessity of looking more into it, with the view of preventing the spread of infection, because it was stated broadly at our Board of Guardians that fever was always existing there.

Did you pave that part?—We have paved it. There is a flat surface for the water to run down; we have drains also.

Mr. Evans. We cannot get a fall sufficient; it is one of the old open ditches.

Mr. Bloyd. The consequence of our paving it was, that the people were so rejoiced that they received us as so many saviours.

What has been the effect upon the health of the inhabitants?—It is only recently done.

Mr. Evans. It has only been done within a fortnight. After it was done I saw, I think, 80 children playing there, from about two years old up to nine; before they could not play on account of the water which was stagnated in those channels. It struck me as a father and a grandfather. I said, "Dear me, if we never did more good than this, we ought to be very glad." I am sure I counted 80 children in those two courts. I wish to impress strongly upon the minds of any gentlemen who have the power of carrying out improvements only to consider the 80 children, and their mothers at the wash-tub. My son-in-law, who is a medical man, and another medical man that I know (and I have been 30 years off and on in the parish offices), always find that, when they get the fever in one house, it runs all through the court like a bit of gunpowder, with which when I was a little boy I made wildfire; it spreads through the neighbourhood. We lose sight of all the back courts.

It is especially in these crowded places, and by the poorest classes of the population that the great benefit would be experienced of such an expenditure of the rates as should effect complete cleansing by combined

works, comprehending internally the distribution within the premises of an adequate supply of water, and the substitution of the soil-pan apparatus for the cesspool; and, externally, proper paving, and the regular application of the hose and jet. The actual obstacles to improvement were thus adverted to by the deputation—

The Commissioners of Sewers expect that powers of going into premises will be requisite; they do not see their way to effect with economy the works required for the private and public benefit without such powers. If those powers were in the hands of a public authority, do you think that, as a householder, or as an owner, you would object to their exercise?—I should not object to them as a householder, and I should think it one of the greatest advantages, if I did, that they should be allowed to come into those parts and clear out the filth and mess, and the running over of the privies, because the property gets destroyed and parties get so annoyed by those nuisances, that many of the landlords never go near the places, they leave it to other hands. The whole of the property is neglected to a great extent.

Mr. Corner. There is no doubt that such powers would be far less objectionable in the hands of a public Board than of a private body. The mischief with regard to those small houses is this, that they are generally in the hands of people who make a large profit out of the money which the labouring man is obliged to pay for his lodgings. That sort of property would only pay people of the hardest and most flinty hearts. The man will go every Monday morning for his rent, and if it is not ready the parties must turn out. A man with anything like kindness of disposition can never make a profit of such property. It is precisely those people who possess that property who will do nothing for the health and comfort of their tenants; it is precisely those people who set their strongest force in opposition to anything like a compulsory improvement of the tenants' premises; it is those people upon whom the screw must be put; it is those people who must be compelled to effect the necessary cleansing and improvement of the places where the poorer inhabitants are obliged to dwell; and it is those people who can pay for it, because they derive immense profits.

As a parish officer, should you say, although that species of property is profitable to the landlords, it is not, from charges on account of sickness and otherwise, profitable to the parish?—It is quite otherwise; it is the great source of expenditure of poor-rates, and the least gratifying expenditure of poor-rates, because it engenders sickness, and disease, and death among the poor, which of course is a much more serious matter than the mere expense to the rate-payers.

But by the proper application of the new system, which provides for an equitable distribution of administrative charges, (which, however, it often appears to be above the competency of the local authorities to apply, and which, if not most carefully guarded in its use, introduces new temptations to shift burthens on absentees and reversioners,) the necessity of a compulsory levy for immediate outlay on permanent works on those who have only a short interest in the property is obviated.

The immediate obstruction even to the temporary extension of the trial works for cleansing the worst conditioned districts, arose from the separation of the several parts of the work, under different authorities. In the first place, the water was in the hands of trading Companies, with the power and the temptation to make a charge, according to the necessities of the public, and at all events, of exacting a profit beyond the actual expense of the service rendered. Such bodies cannot be expected to give the control of the commodity they trade in to officers and labourers not responsible to them. In the next place, the duty of attending to the surface cleansing of the carriage-ways is charged upon a great multitude of parochial and other local bodies, some of whose jurisdictions divide streets longitudinally. At best, the subdivision of jurisdictions would necessitate a multitude of separate bargainings and separate arrangements for a work which can only be properly carried out as part of a general system. The surface cleansing of the streets cannot however be at once separated from the business of removing the dust and ashes from houses, with which it is generally included in one contract.

We have received much evidence to show that these local Boards are often to a great extent in the hands or under the influence of contracting tradesmen, who indirectly procure the return of friendly tradesmen as members,—a result which the rate-payers have but little means of guarding against.

The very little use that has yet been made of the street-sweeping machine may be adduced as a decided

instance of the power of the interests adverse to improvements in cleanliness, inasmuch as by that machine, any given extent of surface is cleansed more effectually than by hand labour, and at one-half the expense.

Unless the cleansing be general and simultaneous, much of the dirt of one district is carried by traffic into another. By the subdivision of the metropolis into small districts the duty of cleansing the *public* carriage-way is thrown upon a number of obscure and irresponsible authorities, while the duty of cleansing the *public* footways, which are no less important, are charged upon multitudes of private individuals. It is a false pecuniary economy in the case of the poorest inhabitants of a court or alley, who obtain their livelihood by any regular occupation, to charge upon each family the duty of cleansing the footway before their doors. The performance of this service daily at a rate of 1*d. per week* per house or per family, would be an economy in soap and clothes to persons, the average value of whose time is never less than 2*d. per hour*. It follows that the false pecuniary economy which charges householders or their servants with the performance of such a labour is proportionately greater.

In Philadelphia the water jet is used for the purpose of cleansing the fronts of houses as well as footways, and paved carriage roads; and it is stated, that its main streets, public buildings, and houses, have all the cleanliness and brightness of a Dutch town, where the fronts of the houses are washed by water thrown from scoops by hand instead of by the more powerful method of the jet. Several of the Local Boards in provincial towns, where there is a constant supply of water, are preparing to apply it to street cleansing, but are waiting for the purchase of the water-works from the water Companies, with whom the arrangements requisite for such applications of water are found to be always inconvenient and often impracticable.

It thus appears that, at a rate of expense greatly below that which would be requisite for a sufficiently extensive system of scavenging or sweeping by hand;

it is practicable to have the foot-pavement of every main thoroughfare as well washed every day and made as perfectly clean as the court-yard of a gentleman's mansion; that, in the same manner, the carriage-way may be rendered as clean and as free from dung and filth as before the commencement of the traffic; and that a like amount of external cleanliness may be economically extended to, and maintained in, the courts, alleys, and back streets inhabited by the poorer classes.

In a street of great traffic, where several loads of dung are dropped during the day, it appears to be objectionable to allow such quantities to remain on the surface, to be trodden about and evaporate during the whole day. It might be inconvenient to use the jet for cleansing during the traffic, and perhaps the most complete arrangement for rapid and effectual as well as economical cleansing, amidst the traffic, would be to have a set of light street-sweeping machines, constantly traversing the streets, so as to remove at once all the filth which may have fallen.

It is estimated that the proposed systematic street cleansing by the jet would require an additional supply of water of about ten millions of gallons per diem. For this service water of a superior quality would be the least necessary; and the mains for this particular service might be conveniently separated from the pipes for domestic supply. Being, however, aware of the sanitary evils resulting from the evaporation of water containing animal or vegetable matter in a state of decomposition, we are of opinion that the use of Thames water taken up near Hungerford market, at the point from which the Lambeth Company receive their water, would, even for this purpose, be objectionable. As the cleansing is effected by the sweep of the water rather than by the solution of solid matter, any of the harder waters might suffice for this purpose. The cost, however, of such a separation of services would be an objection; where the supply of good water is abundantly sufficient for all purposes, no advantage whatever would be derived from such a separation, while for the cleansing of close neighbourhoods

in the heat of summer, water which is cool as well as free from decomposing animal and vegetable matter is desirable.

The method of cleansing, now proposed, offers other important advantages, on which it may be necessary to give further explanation.

For the cleansing by the jet a body of competent and well-directed mechanics and labourers would be required; for cleansing the public thoroughfares however, they would chiefly be occupied in the early morning. They might be employed during the rest of the day in other labours requisite for the complete work of cleansing and the removal of refuse. For a district of an extent, such as is frequently committed to the charge of a person called a "street-keeper," one man might be appointed to conduct the street cleansing in the morning, and during the later part of the day to direct the removal of dust and ashes, and take charge of the apparatus for water supply, and water removal. He should be a mechanic, competent to remedy stoppages or defects in the apparatus, or to take measures for immediately making good any failures in the pavement. He might in place of the turncock have charge of the keys of the water-plugs and hose.

We have anxiously investigated a subject connected with this inquiry, in which the protection of life and property is deeply involved, namely, the best means of providing water for the extinction of fires. The daily occurrence of fires in the metropolis, their extent, the number of persons who perish by them, the enormous loss of property they occasion, the prevalence of incendiarism, the apparent apathy with which such calamities are regarded, and the rapidity with which they are forgotten, will hereafter be referred to as evidence of a very low social condition and defective administrative organization. We feel happy in a confident belief, founded upon extensive evidence, that a system of constant supply at high pressure in its application for surface cleansing, possesses, independently of all other considerations, a high degree of value, on account

of the effectual means which it will afford of reducing the number of destructive fires. First, the system of constant supply night and day at high pressure, upon which we insist, would of itself reduce the destruction by so much as is at present occasioned by the want of water, and the delay in obtaining it; secondly, the provision we recommend of water-plugs at convenient places for the work of surface-cleansing, is precisely the arrangement that would be necessary to bring every description of property within reach of an abundant supply of water, in the shape of one or several jets, applicable in a few minutes, with the full pressure of the main at that point (which would be, at least, equal to the force of the largest engines now used); thirdly, the constant use and practice in applying the apparatus to street cleansing, would ensure its being at all times in a state of efficiency on the occurrence of a fire.

Taking the point of actual ignition, the value of a supply of water diminishes in a ratio rapidly increasing with the lapse of time before the arrival of such supply. In the first minute of the ignition a jugful of water may suffice; in the second minute not a pailful; in the third minute not three or four pailfuls; and in a few minutes more nothing will suffice but supplies that can be applied only by engine power. In the published accounts of fires, it is usually stated that the attendence of the Fire Brigade was "prompt," and that the engines were "soon on the spot." That service in the metropolis appears now to have attained a very high degree of efficiency. But, amidst the alarm on such occurrences time is seldom noted, and must be measured by the operations which have to be most rapidly performed. When the alarm is given, which is usually on the discovery of the fire on the outside of the premises and when it has got to a serious height, a messenger must convey the information to the nearest station; the men must be assembled and conveyed to the spot, the turncock sought, and the plug opened, all operations, when performed in the best possible manner, occupying time

during which the fire is rapidly extending. With the view to determine the loss of time somewhat more closely, we requested the Commissioners of Police to cause to be noted the time which elapsed between the discovery of the fire, and the arrival of the engine. In 17 fires, of which two were in suburban districts, the average loss of time between the alarm and the arrival of the engines, was 36 minutes. Mr. Braidwood, the director of the Fire Brigade, was asked—

What is the average length of time between the discovery of a fire, and the arrival of an engine on the spot?—It depends entirely upon the distance. We have 19 different stations for engines in London (including two floating engines). The average time of an engine turning out with horses is from three to seven minutes.

On further examination, it appears that the engines traverse the streets, allowing for obstacles, at the rate of 10 miles an hour; information will be conveyed to the station of the Brigade at the rate of about five miles an hour: thus in the case of the occurrence of a fire within a mile of a station, the intelligence may be conveyed to the station in about 12 minutes; the horses will be put to, and the engine got out into the streets in about five minutes on the average; it traverses the mile in about six minutes; and the water has to be got into the engine, which will occupy about five minutes, making under the most favourable circumstances for such a distance 28 minutes, or for a half-mile distance, an average of not less than 20 minutes. The average distance of all the fires which occasioned the loss of lives during the last three years, was rather more than the last-mentioned distance. But several were at two miles distance; others from a mile and a half to one mile distance. The average distance of the fires which occasioned the most extensive losses of property during the same period was, according to a return given in by Mr. Braidwood, one mile and three-quarters, but one was five miles, and several were four miles distant from the nearest station. The result is extensive disaster which aid in a shorter time might prevent.

If the arrangements which we propose were carried out completely, we believe that there would be very few cases of fire where the house itself would not be saved. The examination of Mr. Quick develops the main principle of these arrangements. He states,—

After the destruction of the terminus of the South Western Railway by fire, I recommended them to have a nine-inch main, with three-inch outlets leading to six stand-pipes, with joining screws for hose-pipes to be attached, and that they should carry a three-inch pipe of the same description up into each floor, so that a hose might be attached in any room where the fire commenced.

In how many minutes may the hose be attached?—There is only the time of attaching the hose, which need be nothing like a minute. I have indeed recommended that a short length of hose with a short nozzle or branch should be kept attached to the cock, so that the cock has only to be turned, which is done in an instant.

It appears that fire engines require 26 men to work each engine of two seven-inch barrels, to produce a jet of about 50 feet high. The arrangement carried out, at your recommendation, with six jets, is equivalent to keeping six such engines, and the power of 156 men, in readiness to act at all times, night and day, at about a minute's notice, for the extinction of fires?—It will give a power more than equal to that number of men. For the jets given off from a 20-inch main will be much more regular and powerful, and will deliver more water than could be delivered by any engine. The jets at that place would be 70 feet high.

Under a system of constant supply at high pressure, such as that for which you have made an estimate, even the smallest street might be supplied with a three-inch main, affording one 40 feet jet at least, that is equivalent to keeping the power of one engine and 20 men in readiness at every house door, to act at one minute's notice, in case of fire?—Certainly.

Arrangements for fire-escapes or other efficient machinery are, if complete, excessively expensive, or, if inexpensive, generally inefficient. By a diminution of force, the time of bringing the apparatus to bear is fatally increased. To make these arrangements thoroughly efficient, as respects the time of application, one complete set of fire apparatus should be provided for every large street, or for each small sub-district. The objection to this arises not only from the very large expense of the machinery, but the still larger additional expense for its special management, of which

the parochial authorities are wholly incapable. This is proved decidedly by the fact, that there are in the metropolis no less than 150 public fire-stations with engines managed by the parochial authorities, and only 17 land stations of the fire brigade; yet out of every three fires, the engines of the brigade, though from a far greater distance, arrive the first at two of them. On dividing the number of stations by the times of the first arrivals of the engines at all the fires which have occurred during an average of three years, the numbers were 35 for each fire brigade station, as against 2 only for each parochial station. In the smaller districts, however, the fires being comparatively few, the machinery is rarely used; and machinery rarely used is seldom in a condition for use when it is wanted. The establishments which are really efficient being few, additional loss is incurred from their inevitable distance from the scene of calamity.

The objections put in a report by Mr. Braidwood to the establishment of a set of fire escapes under parochial management, is applicable to the present arrangement of distant fire-engine stations, and sets forth the difficulties of their multiplication:—

> Taking London to be six miles long and three miles broad to have anything like an efficient system of fire escapes, it would be necessary to have one with a man to attend it within a quarter of a mile of each house, as assistance, to be *of any use, must generally be rendered within five minutes after the alarm is given.* To do this the stations must be within a quarter of a mile of each other (as the escapes must be taken round the angles of the streets); 253 stations would thus be required and as many men.
>
> At present scaling ladders are kept at all the engine stations, and canvass sheets also at some of them; several lives have been saved by them, but the distance of the stations from each other renders them applicable only in a limited number of instances.

Under the practice which we propose, we think it would still be well worth while to retain the services of such a trained force as the fire brigade, and put it on a more efficient footing.

In many instances a constant supply of water has been sought to be secured by the provision of large tanks. In some cases where the apparatus connected

with these tanks happened to be ready, the efficiency of the proposed system of a constant supply was proved by the extinction of fires, which, if a few minutes delay had occurred, would have inevitably destroyed the premises.

But heavy disasters have shown, that such expensive preparations yield only a very imperfect security. A fire breaks out in the lower part of the premises, and cuts off communication with the apparatus at the top; or the cocks not having been used, will not turn; or in the winter time, when fires are most frequent, the water above is found to be frozen, and will not run in time. At Liverpool, upwards of 100,000*l.* was proposed to be expended (on the advice of an engineer of one of the old London waterworks) for the protection of the warehouses and other property in the town by a system of tanks and cisterns. Mr. Samuel Holme, a builder of that town, having been consulted by warehouse-owners as to the usefulness of tanks or reservoirs at the top of the premises, dissuaded them from this mode of protection, for this amongst other reasons, that they incurred risk of damage to goods from the leakage and overflow of the cisterns themselves. The rent of the large tanks, exclusively of the space they occupy, would often be greater than the cost of the proposed water-supply. Of their failure in case of fire, he gives the following instance:—

Some years ago, the owner of a cotton kiln, which had been repeatedly burnt, took it into his head to erect a large tank in the roof. His idea was, that when a fire occurred, they should have water at hand; and that when the fire ascended, it would burn the wooden tank, and the whole of the contents being discharged on the fire, like a cataract, it would at once extinguish it. Well, the kiln again took fire, the smoke was so suffocating, that nobody could get at the internal pipe, and the whole building was again destroyed. But what became of the tank? It could not burn, because it was filled with water; consequently, it boiled most admirably. No hole was singed in its side or bottom; it looked very picturesque, but it was utterly useless.

The general practice of cleansing courts, alleys, and streets would provide a powerful machinery on the

outside of the premises, at all times and everywhere ready and efficient, because at all times and everywhere in use. If persons in the rural districts wish to protect their property from fire, they may do so far more effectually by a *garden* engine, or any instrument in frequent use, than by a *fire*-engine reserved for extraordinary occasions. For the like reason we may rely with more certainty on several hundred plugs, with hose and jets daily in use for street cleansing, than on the same number of even superior implements reserved specially for fires. The removal and application of a light hose which one man can wield, is easier, even for the same distance, than those of a heavy engine and all the men trained to work it. But hose and apparatus should, for the ordinary service, be kept in each street, or within such short distances, and in such custody that any policeman might, in the absence of the street-keeper, at once fix and apply them. We believe that under a system of constant supply at high pressure by night as well as by day, it might be ensured that the hose should be within reach, fixed, and applied on an average of not more than five minutes from the time of the alarm being given; that is to say, in less than one-fourth of the time within which fire-engines are brought to bear under the existing arrangements, and with a still greater proportionate diminution of risks and serious accidents. Where the constant supply has been introduced, the efficiency of the means here proposed for extinguishing fires has been placed beyond doubt both at home and abroad, even when those means were applied less efficiently than would be practicable under arrangements on a scale befitting a metropolis with upwards of 12,000,000*l.* of house-rental without reckoning the value of stock.

Mr. Emmott, the manager and engineer of the Oldham Water-works, describes the practice in that town in relation to fires:—

In five cases out of six, he says, the hose is pushed into a water-plug, and the water thrown upon a building on fire, for the average pressure of water in this town is 146 feet; by this means

our fires are generally extinguished even before the heavy engine arrives at the spot. The hose is much preferred to the engine, on account of the speed with which it is applied, and the readiness with which it is used, for one man can manage a hose, and throw as much water on the building on fire as an engine worked by many men. On this account we very rarely indeed use the engines, as they possess no advantage whatever over the hose.

In Philadelphia, the system has been tried with the like advantage.

Mr. W. Baddeley, an engineer, who acts as an inspector to the Society for the Protection of Life from Fire, and who appears to have taken, for many years, an earnest interest in the means of preventing fires, gives important and decided testimony as to the effect of saving of time in the diminution of disasters.

You have attended many fires?—I do constantly, and have done so for the last 30 years. I have given a great deal of consideration to the subject of water supply at fires during the last 30 years, and have been in early attendance at all the principal fires in the motropolis during that period.

Between the time of alarm of fire being given and the engine being brought to bear, what time, with the present arrangement, elapses before the engine is on the spot?—At Islington, where I reside, the time might be about 40 minutes; but in the City, where the stations are closer together, the time would be, I should say, from 15 to 20 minutes; there would be 3 minutes for mustering the policemen, and the engine station would be, say 10 minutes off; in 5 or 6 minutes the engine would be got out, and then 5 minutes would elapse before it was on the spot. The turncock is most probably on the spot first, so that 23 minutes altogether would be a fair average time in any city district.

What proportion of fires do you think might be avoided by the adoption of efficient means?—The number of fires last year was 838; and if there had been the means of applying water immediately, two-thirds of them would have been stopped immediately.

Would you say that the means of applying water in adequate quantity within 5 minutes of the commencement of a fire would prevent the progress of two-thirds of them?—Yes, about that time.

In some places has not delay occurred from the turncocks being at wide intervals?—Yes, on the south side of the Thames particularly. It is generally objected by the Companies that none but their own servants shall have command of the fire-plugs in order to prevent confusion, as though it is necessary to have one or two plugs open, it is necessary to close two or three others to get the supply.

Under a high pressure system of course there would be a much stronger jet given than can be procured by an engine?—Yes, certainly.

And you think, with such an apparatus, that two-thirds of the fires might be stopped?—Yes, they might be stopped immediately.

Then, from your experience, you have no doubt that the prompt application of water would be most beneficial?—I have no doubt whatever.

Other inquiries connected with measures for the improvement of the population have developed the operation of insurances, in engendering crimes and calamities; negatively, by weakening natural responsibilities and motives to care and forethought; positively, by temptations held out to the commission of crime in the facility with which insurance money is usually obtainable.

The steady increase in the number of fires in the metropolis, whilst our advance in the arts gives means for their diminution, is ascribeable mainly to the operation of these two causes, and to the division and weakening of administrative authority. From information on which we can rely, we feel assured that the crime of incendiarism for the sake of insurance money exists to a far greater extent than the public are aware of.

Officers engaged in the fire service believe this from *primâ facie* circumstantial evidence,—such as recency of insurance, the parties insured being in debt or straitened circumstances, suspicious facts as to the quantity and value of the furniture and stock consumed, and the time and mode of the fire; and the completion of well-matured plans for the rebuilding of the premises, which must have been prepared before the fire. Into such cases the Insurance Companies do not consider it to be to their interest to inquire, with a view to prosecution, since an offensive strictness of examination must be extended to many cases for the probable detection of crime in a few.

The following case, as given in an annual report by Mr. Baddeley, is illustrative of the condition of the public interests in respect to these cases:—

On Monday, January 15, 2½ A. M., No. 46, Bermondsey-street, a fire broke out. Messrs. John and William Scallard, egg

and butter merchants. At the time stated, 23 persons were located in these premises, when a policeman who was passing, saw an appearance of fire and roused the inmates. It was some time before he was admitted, when he found the shop on fire, as also the cellar. By the prompt arrival of the fire brigade, from Tooley-street station, the fires were soon extinguished.

The fact of the two distinct fires and the absence of property, in the face of a heavy insurance, looked so suspicious, that Mr. W. Payne, the Coroner, held a court of inquiry into the circumstances; when it appeared that William Scallard had insured the stock in the General Assurance Company, for 320*l.*, and soon after the fire, sent in a claim for 128*l.*; viz.: 90*l.* for 40 firkins of butter, and 38*l.* for fixtures; all the stock found in the shop was three eggs and a piece of butter about an inch deep, in the end of a cask.

Mr. Henderson, brigade foreman of the district, said, "Had he not been told by Mr. Scallard, that he was a cheesemonger and egg merchant, he should have returned him as a dealer in *empty* barrels."

A mass of circumstantial evidence inculpating the brothers being adduced, the jury returned a verdict that, "the house was wilfully set on fire by William and John Scallard." The verdict having been returned, the Coroner asked Mr. Oughton, the actuary of the office, what steps the Company intended to take in the matter?

Mr. Oughton. "I am not aware that the Office will do anything. This inquiry is for the safety of the public—Insurance Companies do not like prosecution; but in this case I can make no promise."

The Coroner (with some warmth). "I know what that means; that nothing will be done, and that these men will be allowed to escape, as in previons cases. If I take the trouble to hold these investigations, surely you might assist in punishing the guilty parties."

Mr. Oughton. "We do not like to prosecute; but if an action is brought against us for the recovery of the money, we shall resist and prove what we know."

The Coroner. "Yes, that's it. As long as you have not to pay the money you don't care. I am sure that, by holding these investigations, I have saved the insurance offices thousands of pounds, and I think it, I will not say disgraceful, but highly reprehensible, that I am not assisted. There is no public prosecutor, and unless the office does its duty, these men must escape." The inquiry then closed; the two men against whom the verdict was found, being left at liberty.

The late respected magistrate for Southwark, Mr. Cottingham, seeing these remarks of Mr. Payne, at once ordered the police to apprehend the guilty parties, who were accordingly taken into

custody, and after two examinations committed to take their trial at the Central Criminal Court, where they were indicted for feloniously setting fire to a dwelling-house, the property of Joseph Goodchild, with intent to injure him, found guilty, and ordered to be transported for life.

The metropolis itself is, as we believe, exposed to the danger of extensive conflagration, which, existing means would be wholly insufficient to arrest. If, for example, a fire occurred in a large warehouse in one of the narrow streets, and there happened to be at the same time a hurricane of wind, in a direction to drive the flames across the streets from house to house, the havoc might be as great as any that has been witnessed in modern times.

Mr. Braidwood, being questioned upon this topic, was asked:—

Are there not trades carried on, and deposits of merchandize along the river side, which are rather liable to fires; at least, where there are a great many inflammable materials which would become dangerous, supposing a fire to take place?—Yes; along the south shore from London Bridge we have had some very heavy fires, and great want of water.

That is the very district in which many of those inflammable materials are brought together; a great deal of cordage and marine stores?—There are many hazardous trades mixed up among the warehouses, barge and ship-builders, mast and block-makers, smiths' forges, &c., &c.

The district in which those trades most liable to damage from fire are carried on, has a very bad supply of water?—Yes; it is much the same on the other side of the river, but there is a very good supply of water there.

Have you any suggestions to make for an improved supply of water, or for any regulations referable to the diminution of risk from fire, or the mode of putting out fires in London?—One great advantage, if it could be obtained, would be to have water on night and day, at all times, in all mains and all services.

Would that be attended with a greatly increased cost?—The Water Companies say that it would; I have spoken to one or two about it, and they seem to say that they could not do it.

Would the water being on constantly cause a greater drain upon them than there is at present?—Their idea is, that if the water was on constantly, the people would use it more lavishly.

Is it not generally the case that, even in individual houses, sometimes a cistern below is supplied, and the cistern on the roof not supplied?—Yes; very often.

They have great objection to allow any interference with the main?—Yes.

The warehousemen, or owners of the extensive buildings and stock involved in the dangers described do not use water to any extent for any purpose within the buildings described: the negative effect of the insurance weakens the motive to make proper provision of water on their premises, from which they are further deterred by the exorbitant charges of the Companies, not regulated by the actual expense of the service, but of the supposed necessities of the parties. On the other hand, these Companies, as commercial bodies, cannot fairly be called upon or expected to carry mains where they have no sufficient custom, or to make a special provision of works for which they are not paid.

The provision of water for surface-cleansing would, if adequately made, carry water mains and apparatus for their use in case of fire, amidst blocks of buildings now almost entirely unsupplied with water. The reduction of the cost of water-supplies, if provided at a rate calculated not to produce a profit, but to cover the original outlay, would create inducements to extend the use of fixed apparatus in the interior of buildings for the prevention of fire. The general provision would moreover carry water to the remote and outlying districts which are now unprovided with it.

Observing these elements of insecurity in respect to the fire insurances, we were desirous of ascertaining the proportions of houses and properties burned that are insured, to those that are uninsured. We were informed by Mr. Braidwood, that upon the best means of information at present possessed upon the subject, of the property insured in the metropolis, about one-half, or 50 per cent. only in value, is insured; but as the larger masses of property are the most frequently insured, it would follow that less than 50 per cent. in numbers of properties are insured. The proportion of insured and uninsured houses is not ascertained.

From a return very carefully compiled for the last

14 years by Mr. Baddeley it appears, that the number of fires is increasing; there has during that period been an increase in the number of dwellings, but that has been chiefly in suburban dwellings, in which fires very rarely occur. From these returns the following results are apparent:—

—	Fires per Annum of Houses and Properties.	Of which were Totally Uninsured.	Proportion per Cent. of Insured Houses and Properties Burnt.
In the first seven years there were on an average . .	623	215	65·15
In the second seven years .	790	244	69·3

From a return made by Mr. Braidwood of the houses and properties destroyed in the metropolis, in the three years ending in 1849 inclusive, it appears that the total number was 1,111; of contents destroyed (which being generally insured separately, should be kept distinct) there were 1,013; of these:—

—	Insured.	Uninsured.
Houses . .	914	197
Contents .	609	404
	1,523	601

The proportion per cent. of the uninsured to the insured, would be—

—		Insured.	Uninsured.	Total.
		Per Cent.	Per Cent.	
Houses . .	1,111	82·3	17·7	100
Contents .	1,013	60·1	39·9	100
	2,124	71·7	28·3	100

The frequency of fires led Mr. Payne, the coroner of the City of London, to revive the exercise of the coroner's function of inquiring into the causes of fires; most usefully. Out of 58 inquests held by him (in

the City of London and the borough of Southwark, which comprise only one-eighteenth of the houses of the metropolis) since 1845, it appears that, eight were proved to be wilful; 27 apparently accidental, and 23 from causes unknown, including suspicious causes. The proportion of ascertained wilful fires was, therefore 23 per cent.; which gives strong confirmation to the indications presented by the statistical returns as to the excess of insured property burnt, above uninsured.

The increasing frequency of destructive fires at Liverpool about five years ago led to a close inquiry into their causes by Mr. Rushton, the magistrate, when he was led to the conclusion that a considerable proportion of them were wilful, the offence having been committed to conceal extensive depredations on warehouse property.

The example of Mr. Payne has been followed in several counties, and a marked decrease in the number of fires has been observed, while sufficient reason has been elicited for the belief that a more regular and systematic prosecution of such inquiries would be of great public advantage. We are happy, however, to be able to adduce evidence, that the adoption of the arrangements which we propose for the more quick and effectual application of water to the extinction of fires, would, besides largely reducing the calamities arising from accidental causes, give a very decided check to the practice of incendiarism. The evidence of this is derived from recent experience in the case of Hamburgh. After the destruction of that city it was rebuilt chiefly under the direction of Mr. William Lindley, the engineer, and as he has avowed, so far as he was allowed, on principles developed in the Sanitary Report. In those arrangements which we have already noticed were included works for the total abolition of cesspools, a complete apparatus for the delivery of water into houses, and for the removal of all sewer or soil water. In respect to fires, the arrangements for surface-cleansing by the water jet have been successful not only in effecting the immediate

extinction of purely accidental fires but they have further afforded means of checking the crime of incendiarism for the sake of insurance money. On a recent occasion, when Mr. Lindley was in London, we took the opportunity of questioning him in relation to the progress of the works for the sanitary improvement of Hamburgh.

Being asked —

Is the jet used at Hamburgh for watering the streets?—Yes; the charge has been 1*d.* per foot of frontage per annum.

What provision is made with the new system of works which you have laid down for the prevention of fires?—The mains are large, from 6 to 20 inches diameter, constantly charged at high pressure, being supplied from the one extremity by two Cornish engines, and at the other level from a high summit reservoir, kept constantly filled. Throughout the whole length of the pipeage are placed, at intervals of 40 yards, fire-plugs of 3 inches diameter in the clear.

How soon can a jet be applied?—In two minutes. The men who get paid by old custom for the use of their engines will come, although they are not wanted, but the power of eight engines may be anywhere applied as quickly as the hose can be screwed on, and introduced *inside* the house where the fire is.

Have there been fires in buildings in Hamburgh in the portion of the town rebuilt?—Yes, repeatedly. They have all, however, been put out at once. If they had had to wait the usual time for engines and water, say 20 minutes or half-an-hour, these might all have led to extensive conflagrations.

What has been the effect on insurance?—The effect of the rapid extinction of fires has brought to light to the citizens of Hamburgh, the fact that the greater proportion of their fires are the work of incendiaries, for the sake of the insurance money. A person is absent; smoke is seen to exude; the alarm of fire is given, and the door is forced open, the jet applied, and the fire extinguished immediately. Case after case has occurred where, upon the fire being extinguished, the arrangements for the spread of the fire are found and made manifest. Several of this class of incendiaries for the insurance money are now in prison. The saving of money alone, by the prevention of fires, would be worth the whole expense of the like arrangement in London, where it is well known that similar practices prevail extensively.

The attention of the authorities at Liverpool was directed by Mr. James Macdonald to this application of water under the system of constant supply at high-pressure, and the water apparatus was specially adopted

for the purpose. The arrangements appear to be incomplete, systematic street washing not yet being introduced, while the hose and apparatus for the purpose are kept at distinct stations. It is contemplated to construct lamp-posts, containing a hydrant with a hose and apparatus shut up in the base, for common as well as extraordinary use. The following is the account given by the town surveyor, Mr. Newlands, of the usefulness of even the present imperfect arrangements.

You are aware that in Liverpool, an Act was obtained to establish water-works specially for sanitary puposes, and as a security against fires, and that in connexion with these works, upwards of 12 miles of mains were laid chiefly in the warehouse districts. These mains are kept constantly charged under head pressure from the reservoir at Kensington, which is 226 feet high above the old dock sill, the usual sectional datum here. The security to property from even this limited extent of piping in a town, containing about 400 miles of streets and roads, has been demonstrated to be such, that in the first year of its working, the saving on the premiums of insurance alone was estimated at 25,000*l.* I had the charge of these works on my arrival in Liverpool, and was engaged in perfecting the mode of procedure, in cases of fire. It is this:—at each fire-station, reels of hose, each mounted on a light hand-cart or barrow, are kept; the bottom of the barrow forms convenient lockers for containing the stand-pipes, nozle and tools, and the whole apparatus is so light, that a man can run with it. On notice of a fire being received at the station, a couple of men set out immediately with one of these reels, others follow, and the remainder of the force busy themselves in turning out the engine and water-barrels, in case the fire should be in an elevated district, where there is not sufficient pressure. On arriving at the fire, the stand-pipe or pipes are put down and the hose run off the reels in an instant, and it may be a dozen jets are playing, and the flames nearly extinguished before the engines have left the yard. Since the water-works generally were put under my management, I have constantly pumped from all the wells where the engines had sufficient power, into the reservoir belonging to the water-works before referred to, and having connected the old mains and services throughout the town with the mains from this reservoir, water jets under high-pressure are available over nearly the whole of the town. Serious fires are now seldom heard of, for before the flames can gain head, the jets can generally be played upon them, and this is the only time that there is a chance of subduing them.

At present, when fires get head, the quantities of water required for the protection of adjacent buildings as

well as for the extinction of fires, are often so large, that the damage from water is as great as the damage from fire. Under the arrangements which we contemplate a less rather than greater quantity of water than is now consumed would be required for the extinction of fires.

Bearing in mind the important declaration made by Mr. Braidwood in respect to fire escapes, that assistance must, "to be of any use, generally be rendered "within five minutes after the alarm is given" we cannot but conclude, that it would be well worth while to make the change to the system of constant supply, were it only for the sake of the effectual provision which would thus be secured for the extinction of fires; that this would furnish the means of giving the required assistance in less than five minutes, or less than one quarter of the present average time of the arrival of engines; that it would afford the means of speedily extinguishing two-thirds of the ordinary fires; that it would reduce the insurance risks in still greater proportion, and that it would operate as an important check to the crime of incendiarism.

In addition to the services for which improved and additional supplies of water on the constant system are required such as domestic use, baths, surface cleansing, protection against accidental fires and incendiarism, we find that the improved system would facilitate and promote new and important applications of water for engine-power.

In the course of his inspections of northern towns, Mr. Rawlinson found hydraulic cranes invented by Mr. Armstrong in daily use on the quays at Newcastle-upon-Tyne.

The principle of the distribution of hydraulic power for these purposes may be thus stated:

It being possible by the Cornish engine to lift 87,000 gallons, or upwards of 388 tons of water, 50 feet high for 6*d.*, or 100 feet high for 1*s.*, that weight of water may be distributed at this cost, plus the expense of pipes, as power to move machines by its descent: and indeed after its descent, the water when so distributed,

may still be used for common purposes at a lower level. There are various convenient and economical modes of applying water to gain intermittent power. Although it is not so cheap as steam-power for large and continuous applications, excepting where there is a natural fall, yet for intermittent applications it is cheaper. A warehouseman, for instance, might desire the power of a small steam-engine to work a crane to unload or load two or three carts or waggons; but it would not be worth his while to keep a steam-engine in readiness for such a service during the whole day. Steam-engines, moreover, require skilled superintendence. With a constant supply of water, a tap merely is turned, and the hydraulic pressure becomes a means of motive power, as in the Bramah press, or any engine on a similar principle, while the power is applied at once, and may be immediately discontinued. Steam is not at present conveniently or economically applicable by common engines for less than two or three horse power, even for continuous work. Hydraulic power is however applicable to exert any amount of force, from that of the largest engines down to that for which smoke-jacks are employed.

In a consideration of the means of improved ventilation, the want has been much felt of a convenient power for the continued and regular application of small forces, as one horse, half horse, man, or boy power. Ventilation dependent on the ascent of heated air, or on thermometrical conditions of the atmosphere, is irregular and uncertain in its action, and, at the time when it is most needed, utterly fails. For this reason we have found it necessary to recommend the application of mechanical power for ventilation, as indispensable for large buildings, or places containing considerable numbers, when regularity in the supply of pure air or the discharge of vitiated air is to be ensured with certainty. A small power was required to move a pump for ventilating the Hospital for Consumption; hydraulic power was recommended, but in consequence of the expense or difficulty of obtaining a sufficient quantity of water delivered at high service, a small

steam-engine has been used, to which is attached a new contrivance for self regulation. Steam-engines require to be examined at short intervals; and for continuous work through the night need two attendants. But it has been found practically that a pump with one of Dr. Arnott's curtain valves which may be worked by a man will ventilate a building containing 500 persons. (*Vide* Report on Quarantine, Appendix, plan of pump as applicable to the ventilation of ships.) Very small powers would suffice for the regular ventilation of private houses; to such purposes hydraulic power made available by the institution of a constant water supply would seem peculiarly applicable.

In any case, however, where the main was irregular in its action, a small cistern on the plan recommended by Mr. Quick would suffice.

Mr. Philip Holland thus illustrates the convenient application to industrial purposes of the hydraulic power derivable from the constant supply.

Do you anticipate still further new demands for water?—Yes, many. For instance, at present many tradesmen employ very small steam-engines for purposes that may be almost as cheaply accomplished by hand, for instance, coffee grinding. There are many purposes for which steam might be substituted for manual power with advantage were it not for the cost of the skilled labour required to attend to it, and the expense and trouble of keeping up the steam when the power is not wanted. If some hydraulic engine, such as the tourbine, were employed, and worked by water from the pipes, which could be set at work and stopped in an instant, which consumes no power except when at work, which requires no skilful mechanic to work it, and is quite free from risk from fire or explosion, there is no doubt that numerous applications of such power would be introduced which are as yet scarcely thought of. It would be easy to work cranes and hoists for raising and lowering goods and persons in warehouses, where the occasions for their use are not sufficiently numerous to make a steam-engine economical. Such an instrument would work presses in the smaller printing-offices, where it is not worth while having a steam-engine. For many purposes a simple hydraulic press with a large cylinder acted upon the direct pressure from the pipes would be sufficient for packing. In others Bramah presses might be worked by the hydraulic engine. Turners might work their lathes, and smiths their bellows, by water-power; chaff might be cut, and oats and beans crushed by the

same means; in fact, it is impossible to mention all the various uses to which it might be applied, if water were supplied constantly and at high pressure. I have no doubt that an extensive new trade will gradually grow out of the application of water-power to small purposes, when the system of constant service at high pressure shall be in operation in London, Manchester, and Liverpool, and the other great seats of industry. In order, however, that this may be the case, the supply must be ample, and the charges to large consumers very moderate.

But with such charges could a fair income be derived by supplying water for these mechanical purposes?—No doubt of it. I have known a warehouseman pay 20*l.* a year rent for the occasional power derived from a neighbour's steam-engine, for working his packing-presses. Many persons now employ little steam-engines, which are uncertain, troublesome, and dangerous; if the same power were given by water without the trouble, uncertainty, and danger many more persons would employ it than now use steam-engines, and the cost might be far less than that of the engines, and yet leave a handsome profit on the cost of procuring the extra quantity of water required.

What is the source of such economy? Would it not require as much extra power to lift the water required to work these hydraulic engines as they can possibly exert?—Certainly, more by the friction lost. But large engines are employed for pumping, and small ones are got rid of; and the cost of a small engine is very great in proportion to the power it exerts, especially if it be not worked constantly; the cost of attendance, repairs, &c., being very great in proportion to the power. With simple hydraulic engines, on the contrary, no special attendance would be required, and there need be no expense incurred except when the engine was actually at work. The supplyers of the water and the employers of the power would divide the resulting advantages, the former might sell this power (for small purposes and for only occasional uses) for much more than it costs. and yet supply the customer with power for such purposes cheaper than he could obtain it in any other way.

And you think there would be a large demand for water for such purposes?—No doubt of it. At a very small cost any persons wishing for the services of a one or two-horse engine for an hour or two a day, might have it without trouble, risk, or uncertainty; and there is no doubt that such an advantage would be very extensively used. Though the introduction of such novelties would, of course, be gradual, I do not think it would be very slow if the charge for the power were not very much more than the cost of raising the additional water required and the expenses attending its distribution.

Although this introduction of hydraulic power would

probably in no case supersede existing steam-engines excepting those of the smallest class, yet having regard only to the public health we submit that it is desirable that such applications of power may be promoted as will in any degree tend to check the multiplication even of small steam-engine furnaces and the aggravation of the smoke nuisance.

It is probable that many brewers and manufacturers who now use deep well water for the sake of its greater coolness and comparative purity, would prefer the improved supplies.

V. Having thus considered separately the chief special uses to the population of improved water supplies, we now beg leave to submit the results of our inquiries, as to the quantities required, the means and expences of gathering and storing them, and of completing an amended system of combined works, for distributing pure and removing refuse water.

It is estimated that the following quantities of water would meet the present necessities of the metropolis.

	Gallons.
1. An improved domestic supply of 75 gallons per diem to 288,000 houses	21,600,000
2. Supply for new baths	1,000,000
3. Supply for the general surface-cleansing of courts, foot-pavements, and the carriage-ways of paved streets, and street-watering .	10,000,000
New demands for brewers and other large consumers	4,000,000
Fires and contingencies	3,400,000
Total daily supply . . .	40,000,000

Those whose duty it has been to examine the sanitary condition of the population of the metropolis, with a view to its improvement, will have their hopes exceeded if the whole of this amount of consumption could be actually and early realized by the execution of a combined system of works. To supply this demand and any probable extension we have the following estimated quantities of water available from the proposed new gathering grounds, as calculated from

the extent of area and from gaugings* taken at the end of nearly six weeks of dry weather :—

	Gallons per Day.
From surface-gathering grounds of sand, comprising specimens averaging from one-third to one degree of hardness, and equal in quality to the water delivered at Farnham, from which district, and from streams derived from similar grounds, the average hardness may be estimated as under three degrees . .	28,000,000
From certain tributaries to the river Wey, containing some water from the chalk, but of a general quality of hardness one-third the average of the present supply of the metropolis	60,000,000
From other tributaries to the Wey, of a harder quality, but only one-half the hardness of the present supply to the metropolis . .	90,000,000

Dr. Lyon Playfair, Dr. Angus Smith, and Professor Way, who have had the largest experience of waters derived from gathering-grounds, have no doubt, nor have any of our Inspectors, that by taking the supplies from the surface, as the water is in fact now delivered at Farnham, the supply of the metropolis would be superior in quality to that of any capital in Europe as far as their information extends. They, and the engineering inspectors, however, express a confident opinion, that by practicable improvements of the surface of these gathering grounds, the quantity of water derived from them may be yet further increased, and the quality improved.

If there can be any reasonable doubt of the sufficiency of supplies from the gathering grounds in question, during periods even of drought, there might still, as a matter of necessity, be obtained on extraordinary occasions supplies of water from the Thames, or the near tributaries to it, for which some of the old works, might still be kept up, such as those of the Grand Junction and Vauxhall Companies, with their filter-beds, which might be prepared and put in action for an emergency. But on the best inquiry we have been enabled to make, with a quantity of more than four

* Gaugings of several of the streams were taken by Mr. Sherwood, an engineer residing in the locality, who has assisted in the inquiry.

times the estimated, and nearly four times the actual consumption, we find no experience to justify such apprehension of deficiency, either for the demands of the rapidly increasing population, or for the extended uses which have been adverted to. The engineering inspectors believe that storage room for sixty days' full supply would be an adequate provision.

At some stages of this investigation, we deemed it expedient to examine all the more obvious available sources of water supply for the metropolis in the four counties within its immediate vicinity. Captain Vetch has examined the various streams on the north and south sides of the river, on the hypothesis that additional quantities of water freed from the impurities of the Thames, might be required. The information contained in his evidence is of high value, as displaying the engineering character of existing works, as also that of several of the proposed schemes of supply. It will be found that he vindicates the superiority of the ancient method of conveyance and delivery of water by means of a covered aqueduct. His plans are such as might be expected from an accomplished engineer, who had done his duty by availing himself of the results deducible from the actual working of modern, or the remains of ancient works.

We had considered that, pending the permanent change of system, and preparatory to it, measures of preliminary but important benefit and economy might be executed.

The engineering inspectors agree that the two establishments which are the most efficient and most eligible, as having superior filtering reservoirs, and as being highest up the river, the Grand Junction water-works on the north, and the Vauxhall works at Battersea on the south side, which now pump water in only during 12 hours out of the 24, might, by some alterations and by rendering their pumping constant, more than double their present delivery, and give a constant supply for a great portion of the metropolis.

According to the analysis of the water at its sources, but more especially as delivered, the river Lea and the

New River waters present no advantages over Thames water taken above the direct influence of the London sewerage. As delivered unfiltered, they appear to be decidedly inferior to Thames water filtered, taken at any point above Battersea. The New River and the East London Companies have no filtration reservoirs which could put them on an equality with the Companies above mentioned much less give them any advantage in any point that could render their collecting and storage works of more use during the period which must elapse before the necessary arrangements can be made for the introduction of a new supply.

Before the sufficiency of the new gathering grounds was so satisfactorily established, and when it appeared probable that improved supplies could only be looked for (except at very considerable distances from the metropolis) from land drainage, involving such a selection and preparation of less eligible sites, might involve a delay of two, and probably three years, before new supplies could be obtained, we considered the eligible course for intermediate adoption to be an extension of the sources of supply higher up the Thames.

Eel-pie Island, beyond Twickenham, was fixed upon, as being on the whole a good position for a pumping establishment, which might, however, be fixed higher up, at an extra expense of about 10,500*l.* per mile. But no equivalent advantage appeared to be obtainable by taking the water beyond Twickenham or Thames Ditton.

Mr. Quick, the engineer of the Vauxhall and Lambeth Company, and consulting engineer of the Grand Junction Company, who is technically acquainted with all the metropolitan water-works, was requested to state what would be the expense, according to his own view, of obtaining a full supply of water from the river at Eel-pie Island, and delivering it filtered into the existing distributory apparatus for the whole of the metropolis, dispensing with all the existing pumping establishments. He shows that for works by which fifty millions of gallons

might be distributed daily the total outlay requisite would be about 300,000*l.* The present annual expenditure in carrying on the works of the seven existing Companies is estimated at 150,000*l.*; the annual expenditure for carrying on the improved works Mr. Quick estimates at 85,000*l.*, making an annual saving, derivable from consolidation, of 65,000*l.* per annum, in addition to the great improvement which certainly would be thus effected in the quality of the supplies. We believe, however, that the saving to be made, by dispensing with the existing establishments, would amount to a much larger annual sum.

This plan, as well as the plans of Captain Vetch, presents strong contrasts with, and suggests instructive commentaries on the several trading schemes pressed for adoption and supported by the parishes.

These intermediate improvements, however, which had suggested themselves would appear to be unnecessary under the favourable conditions which present themselves in the proposed field of supply. Our engineering inspectors are of opinion that these new supplies might be brought to the metropolis in about twelve months from the time of possession of the land. The alterations which would be necessary to bring to bear either of the intermediate improvements could scarcely be accomplished in less time, and would involve a very considerable outlay.

The expenses of the several schemes which we have had presented to us, as far as estimates have been given, would be—

The Watford scheme, for bringing 8,000,000 gallons per diem (modified from Mr. Robert Stephenson's plan)	£350,000
Mr. Hawksley's Bray Lock scheme .	746,790
The Maple-Durham scheme . . .	1,200,000
The Henley scheme	2,000,000
The Medway scheme	400,000
Mr. Barlow's scheme for the south of the metropolis	320,000

It is, however, to be observed of several of these schemes, that they propose to supply the works of the

present Companies, and contemplate a continuance of the several pumping works and open reservoirs near houses, with their expenses, all of which ought to be discontinued for the sake of the improved aëration and purity of the water as well as of economy. Neither the scheme of Mr. Robert Stephenson, nor any one of the others, adverts to the means of carrying away the soil water, as a subject which had entered at all into consideration, yet the extra quantities of water proposed to be supplied would be in excess (above the proved actual consumption of the middle and higher classes), for one plan three times, and for two others four times the total amount of rain-fall over the covered metropolitan area. All this excess must, on the several plans proposed, (which merely contemplate giving additional supplies to be distributed by the existing uncombined works,) throw intermittent floods upon Lambeth, Rotherhithe, Bermondsey, and all the lower districts on the Surrey side of the river; and upon Tothill-fields, Westminster, Wapping, and all the districts below high-water mark on the northern bank of the Thames.

In illustration of the actual evils of the multiplication of capitals and unnecessary works in the same field of supply, we would here recal attention to the special advantages derivable, apart from the proposed substitution of soft for hard water, by the existing consumers of pipe water from the adoption of the system of constant supply and the consolidation of existing intramural distributory apparatus, on the plan admitted by Mr. Quick to be practicable, with a saving of 65,000*l.* per annum in the management:—

1st. The delivery of filtered water to all the consumers of the West Middlesex Company, the New River Company, and the East London Company, who now receive it unfiltered; and to those who now receive it filtered, its delivery in a still purer state from having the work of filtration more carefully performed.

2nd. The delivery of water fresher, cooler, free from the atmospheric impurities imbibed by stag-

nation and exposure in butts and cisterns in close polluted neighbourhoods, and for all these reasons in a condition far better for drinking.

3rd. The delivery in unlimited quantities for baths and washing, without the expense of large cisterns, and without the inconvenience of emptying water-butts, or of interrupting the ordinary domestic supply.

4th. The avoidance of excessive damp arising from the storage of water in and about premises, from evaporation, from the leakage of butts and cisterns upon walls and supports; and from the permeation of the excess of waste-water about the foundations and over the whole site.

5th. The avoidance of the expense of maintaining butts, cisterns, and tanks, and their connected apparatus, and the saving of the cost of repairs.

6th. The gain in space at present occupied by tanks and butts, estimated for the reception of twenty millions of gallons per diem.

7th. The gain of facilities for cleansing close courts, and surfaces of street pavements and walls, by the jet d'eau.

8th. The additional protection from fire, and a saving of the losses and insurance risks to life and property, to an extent of two-thirds, by placing at command in two or three minutes at every point a supply of water equal to one fire-engine, or more.

9th. The immediate gain in facilities for future improvements.

In the examinations made into the sanitary condition of towns with a view to the application of the Public Health Act, we directed the engineering inspectors to avoid entering upon any investigations, as to the value of water-works of existing Companies. We did so, because such investigations would generally have occupied more time in each case than the main inquiry, and under such powers as we possessed would rarely have been concluded satisfactorily either to the Companies on the one hand or to

the rate-payers on the other. The inspectors were directed to examine all the available sources of water supply within reach of the place, to collect specimens and to send them to London for analyses. These were subsequently examined by Dr. Lyon Playfair, in the laboratory of the Museum of Economic Geology, and a disinterested judgment obtained as to which appeared to be the best source; whether that from which the present Companies were supplied, or any other. As the sources of supply are generally rivers or common streams, the Companies have no property in the water itself; their capital consists in their machinery and distributory apparatus, and so much of it as provides for the internal distribution, which may generally be adapted to the distribution of water from any source.

Whatsoever might have been the origin or the conduct of the Companies, there would, probably, in case of such a change of system as we would recommend, be no other disposition on the part of the public but to pay the Companies, fairly and liberally, the actual value of this stock. The determination of that value would, however, be the subject of a separate inquiry. To sanction the investment of new capitals for the introduction of new works whilst there are existing works capable of rendering the service as well, or nearly so, and at reasonable prices, is merely to give a licence to the enterprize of professional persons, who gain in any event, even in that of great public loss. But water Companies, however they may have been originated and conducted, have, we apprehend, no more claim to be protected against improvements, than have the owners of stage coaches, or posting-houses, or the shareholders of canals and turnpike trusts against railways, or railways themselves against each other in the case of competing lines.

Inasmuch as it was requisite in recommending new supplies that the rate-payers should be aware of the probable outlay required for them, the engineering inspectors were directed, when making examinations for the application of the Public Health Act to provincial towns, to estimate the total expense at which complete and combined works could be executed *de novo*, accord-

ing to the most improved principles. If estimates made with this main object happened to present a standard of value for any existing works, or for the fairness or the unfairness of the charges of existing Companies, it appeared to be a standard which it was due to the parties to present to them; if the estimates were erroneous or unjust, they would be subject to correction by subsequent special adjudication.

We have endeavoured to pursue a similar course in respect to the present metropolitan inquiry. We have caused the qualities of the existing sources of supply, and of all such other sources of supply as promised improvement, to be examined, with a view to the determination of the best available source, independently both of existing Companies and of new schemes.

With a view to ascertain the quantity of waste water, for the removal of which it was requisite to provide upon any system of combined works, and to determine what, if any, additional quantity of water was required, we deemed it of importance to verify the actual amount delivered in the metropolis by the Companies. Having done so proximately, as we have already shown, by obtaining gaugings of the run of water through the sewers on days when there was no rain and when the run must have been derived almost exclusively from the pipe water supplies, we considered that it would be satisfactory to examine the capacity of the several Companies' works, to ascertain the quantities returned as delivered, and to receive such evidence as they might give of the actual delivery. Mr. Cresy, one of our inspectors, examined the several works with these objects, and on the whole he verifies the accuracy of the returns and gaugings. Beyond this, we requested the Companies merely to make up to the present time the returns previously submitted to Parliament with some minor additions.

We have as much as possible foreborne entering into the complaints against individual Companies, or scrutinizing the merits of their several internal managements. With the exceptions above stated, we have

endeavoured to confine ourselves to those points of investigation which were open to external examination, such as the qualities of the supplies at their sources, and as delivered.

It is proper however, to state, that the Companies and their officers have answered satisfactorily such questions as we thought it necessary to put to them.

With respect to the general new estimate for combined works of water-supply and drainage, there appeared to us to be an additional cause for it, irrespective of the reasons already stated, in the fact that there are not only large blocks of houses in the poorer districts which have no house supplies of water whatsoever, and are dependant on shallow wells, but numerous and increasing suburban blocks of houses to which no existing Companies' works extend, and for which entirely new provision must be made.

The Legislature has already sanctioned the principle of a free provision of water for new purposes, independently of existing Companies, by enabling the Metropolitan Sewers' Commissioners to sink wells and provide distinct supplies for any of the works under their management and control. These supplies would include water for surface-cleansing and for all other than domestic purposes. The water Companies' terms having been deemed ineligible for the supply of the fountains at Trafalgar-square, an artesian well was sunk for the purpose, and supplies of water obtained, not only for them, but for the public offices and establishments in Westminster.

To what we have already stated on the subject of a purchase of the works of existing water Companies, we must add, that we have been able to fix on no general preappointed principles or terms of purchase, inasmuch as each set of works appears to us to have its own distinct value, and each Company its own special case.

The difficulty of settling the amount of compensation, the wide differences of opinion which are likely to be entertained as to actual value, and the interest which ratepayers must take in the subject, incline us

to recommend that the value of the works should be determined either publicly by special arbitrators, in the mode and on the conditions prescribed in the Public Health Act, or by jury assessment.

The conclusion will have been suggested from a consideration of the facts set forth in the first part of our Report, that it would be impracticable to execute the combined works by or through the management of joint stock Companies, as such bodies, if there were one Company only instead of nine, are deficient in the power of ready adaptation required for carrying out a change of system.

It will have been perceived that we deem it to be essential to an economical as well as efficient sanitary improvement of the metropolis that combined works shall be carried out under one management. The less the extent of the executive agency, the greater will be the concentration of responsibility, and the chances of early and successful execution. We, therefore, feel compelled to recommend, as the only means of effecting the requisite combination of works, an extension to the metropolis of the Public Health Act, with those additional provisions as to the special nature of the administrative machinery, and means of public responsibility which the extraordinary nature of the case may require.

We have directed a careful inquiry to be made into the expences, as well as the engineering means of effecting this combination.

The survey recommended in the First Report of the Metropolitan Sanitary Commission, as an undertaking which must be accomplished before any large or general work could be commenced, is now sufficiently completed to remove all cause of further delay on that account. Existing works and sewers to the extent of four hundred miles have been examined and their condition ascertained. The execution of combined works may now be proceeded with, in whatever district it may be convenient, without the danger of interference with any general plan.

Humanity, strict justice, and the unquestionable

intentions of the Legislature would dictate that works of amendment should be commenced in those districts which are the most severely ravaged by epidemic disease. But those densely crowded low-lying, and ill-built neighbourhoods are the places where the execution of complete works is generally beset with the most difficulty. A sufficient number of them have, however, been examined, and plans and esitmates prepared house by house, in different quarters of the metropolis, such as Bermondsey, Whitechapel, St. Giles, and that part of Kensington inhabited by the poor Irish, to afford safe data for the execution of combined works.

We may cite, as the most satisfactory example, that of a block of 1317 houses, occupying 41½ acres comprising Jacob's Island, Bermondsey. In this block, the number of cesspools was 648 ; there was no house drainage. The deaths from ever present epidemic disease were numerous. Complete plans and surveys were prepared for its sanitary improvement by Mr. J. Grant.

The principle on which the Surveyor was directed to make the survey was, to ascertain at what expense and within what time the distributory apparatus for water could be carried into each house ; sinks and tubular house drains laid down for the constant removal of soil-water from each house ; the cesspools filled up ; and soil-pans, or an apparatus of the nature of a water-closet, substituted ; and proper dustbins, or means of collecting surface accumulations provided. We must premise with reference to the estimate, that, the expence of the collection and storage of water, 26 miles distant, bringing it into the metropolis, and distributing it by a constant supply, would be defrayed at an average cost of not more than one penny per week from this class of tenements. The expense would, with the minor distributory apparatus, stand thus,

	Annual. s.	d.
Expences of main water apparatus	5	0
Service pipes for delivery into each house . .	1	10

	Annual. s.	d.
Sink; tubular branch sewer and house-drain from the house, and filling up cesspool, and soil pan	4	2
Permeable house-drain	0	3
Dustbin	1	0
Total . . .	12	3

or a total weekly rate of less than $2\frac{3}{4}d$. per house.

The average expense per house in one block of 402 houses in Gulstone Street, Whitechapel, distinguished as a seat of epidemic disease, has been estimated by Messrs. Phillips and Gotto, at 3*l*. 3*s*. $8\frac{1}{2}d$. for a combination of apparatus for delivery of water into the houses; for complete house drainage; yard and kitchen sinks; emptying and filling up cesspool, and substituting soil-pan apparatus; and making good the pavement.

The total expense of private works for water delivery to this class of houses, for the removal of soil-water, and for external cleansing by the jet may then be defrayed at a cost of about 3*d*. per week. We have, however, reason to believe that it might be executed at a much lower rate of charge on extended contracts.

The expense would be nearly double if the works were to be executed by each owner separately, and must then involve large immediate outlays for permanent works to be executed by persons commonly having short and variable interests in the premises, a course which, upon local examination, is declared by all the competent officers, to be impracticable. On the other hand the execution of such works, if paid for by distributed charges and improvement rates, they declare, upon personal communication with owners as well as occupiers, to be both practicable and acceptable. Still, however, if such works were to be executed even under the new system of distributed charges by improvement rates, but executed separately—the water apparatus by one independent authority, the drains by another, and, as is at present the case, almost always at different times—the expense would, under the most

economical arrangements, be augmented by nearly 19 per cent.

But even after the execution, the expense would be further augmented considerably by separate jurisdiction and management.

The foregoing estimates include the expenses of service and branch water pipes, also water mains, and the general establishment of that part of the service; sinks; return pipes; house drains; cleansing apparatus and branch drains; but they do not include the expense of trunk sewers and general drainage works.

These estimates have been carefully made for several districts; and the data on which they are founded have been examined.

The engineering inspectors are clearly of opinion, that the least expensive and only effectual mode of relieving the lower districts from soil-water, and also from rain-water, will be by pumping; whilst our medical inspectors urge that intermittent drainage, and the consequent retention of deposits and stagnant sewer water beneath habitations, for any periods, however short, ought to be strictly prohibited.

In the city of Paris, where there is a defective system of water distribution, the supply to a large proportion of the houses is by hand. The removal of human excreta received and retained in large and carefully constructed cesspools, is there effected without the aid of water; that is to say by hand-labour and cartage, and the attention of so many men of scientific ability has been directed to the removal or palliation of the evils of that system, that it appeared to be important to have their various expedients and the practical results therefrom examined.

Mr. Rammell, one of our engineering inspectors, undertook the task. His report, which we have given in the Appendix, we consider to be a very important and instructive document. He shows, that by combined works of water supply and drainage such as we propose for adoption, the lodgment of any decomposing refuse beneath the site may be removed, and a saving of upwards of 40,000*l.* per annum upon the existing

charges for cleansing effected in the French metropolis.. He reports that, as here, " the cesspool system " presents an obstacle to the proper extension of the " water supply, and consequently represses the growth " of habits of personal and domestic cleanliness, with " all their immense moral results; and that, in this " respect, it may be said to be inconsistent with a high " degree of civilization of the masses of any commu- " nity." The case of the removal of refuse from districts below high-water mark, being analogous in the present condition of the sewers, to that of its removal from extended cesspools, we directed Mr. Rammell, from the special attention which he had given to the practical application of the principle of removing refuse in suspension in water, to consider of its application to tbe lower districts of Surrey, and to estimate the expense of relieving that area by pumping, and discharging its refuse at a point where the tide should not bring it back again within the precincts of the metropolis.

It will be seen that Mr. Grant's estimate of the expense of the intermittent cleansing and flushing of the main sewers amounts to an annual charge of 2*s.* 6*d.* per house per annum. It appears to us, however, inequitable, that the whole charge of removing soil or storm-water from the upland districts should fall upon the occupiers of the lower districts who are encumbered by it. From the tables which Mr. Rammell gives, " it " follows, that to pump and provide for the discharge " of the sewage, including 2 feet in depth of rainfall of " the district, would involve an annual charge per house " and per inhabitant as follows:—If spread over the " district and discharged at Deptford, per house 1*s.* 0½*d.* " (12·33*d.*) per inhabitant 2*d.* (1·97*d.*) Discharged at " Woolwich, per house 1*s.* 10¾*d* (22·56*d.*), per inhabitant " 3¾*d.* (3·61*d.*). Discharged at Erith, per house 2*s.* 8¾*d.* " (32·71*d.*), per inhabitant 5¼*d.* (5·23*d.*) If spread over " the entire metropolis and discharged at Deptford, per " house 3¼*d.*, per inhabitant ½*d.* Discharged at Wool- " wich, per house 5¾*d.* (5·67*d.*), per inhabitant 1*d.*

"(0·90*d.*). Discharged at Erith, per house 8¼*d.* (8·21*d.*), "per inhabitant 1½*d.* (1·31*d.*)."

In Holland, three large Cornish engines, erected under the direction of Mr. Arthur Dean, pump out from an area four times as large as the covered portion of the metropolis, ten times as much water as is pumped into London by all the existing Companies.

We might base our recommendation in respect to the lower districts on the long practical experience of the relief of extensive districts in England from surplus water by pumping. In Lincolnshire, the expense of pumping away the surplus rain-water averages 2*s.* 6*d.* per acre per annum, including all expenses of working with engines not of the most recent or improved construction. Calculating, however, that the expense of pumping the soil-water, or waste pipe-water, in addition to the rain-fall, would cause a cost 12 times greater than is incurred in agricultural fen districts, or 30*s.* per acre covered with houses, per annum; as there are in the lower districts of the metropolis about 20 houses to each acre, and as the operation would extend only to about half of the metropolitan area, the annual charge per house spread over the whole area would be 9*d.* per house per annum; but in this instance, as is shown in almost the whole range of the investigation, the rate and the outlay would be a means to the reduction of existing charges.

The plan on which many on whose opinion we are inclined to rely are agreed as most eligible for the discharge of surplus soil-water, would be to send it from the town, through pipes, skirting the cultivated lands, letting out any required portion of it as manure, and discharging the surplus below Erith, or so far down the river, on either side, that no portion of it could be brought back by the return tide to any part of the metropolis. This special work they estimate may be accomplished for a total outlay, inclusive of engine power, of 350,000*l.* This plan may be resorted to until an improved system of cultivation and application of manures shall avoid any waste whatsoever

of the soil-water. But this is a subject which requires a further provision for its proper prosecution.

The engineering inspectors agree also that the pollution of the Thames may, (under a combined system of works, reducing the present excess of waste or soil-water by a constant system of water supply, and thus reducing its bulk and economising its removal,) be prevented at an annual outlay of 10,000*l.* beyond the expense which must be incurred to convey the sewage into the river at Woolwich, as has been proposed, that is, within a distance at which it would be brought back by the tide nearly into the centre of the metropolis.

The gross approximate estimate for the proposed public works of water supply and drainage would be, according to the views herein expressed:—

Storage reservoirs, and intercepting culverts on gathering-ground; covered aqueduct thence to service reservoirs; covered service reservoirs and filter beds; principal mains from reservoirs, street and branch mains, and services, &c., &c., over the whole district; including land for works and compensation	£ 1,432,000
Main intercepting lines of sewers for upper districts; discharge lines of sewer for lower districts; connecting lines of sewer and pipes to and from engines; engines, buildings, &c., &c. . . .	710,000
	£ 2,142,000

The total of the several estimates presented of combined and complete works, consisting of public works of water supply, with mains, service-pipes and apparatus to houses, public works of main, intercepting and discharge lines of drainage, branch, house and subsoil drains, sinks, traps, and dustbins; the soil-pans; engine power, together with the current expenditure on pumping to effect both a constant water supply, and constant drainage; surface-cleansing of streets and courts, and the relief of the Thames from its pollutions, would thus give, under combined management and extended contracts, an average charge per house over the

whole of the metropolis of about 5*d.* per week; a sum less than the present average charge for a defective and partial water supply alone.

Against these expenses, however, must be set off existing charges which would be avoided; repairs of house drains at an average in some districts of 10*s.* per annum; emptying cesspools at an average when properly executed of 20*s.* per annum, and the great annual saving which would arise in establishment charges from combination of management.

In the house-to-house inquiries before alluded to, addressed to householders by the Metropolitan Sewers Commission, were included several questions as to the expenses of the existing works of drainage and water supply during five years. Some of the householders could not make the returns, from not having been in occupation during the whole period, and others from not having the accounts at hand. A sufficient number, however, did give answers, and the following results are similar to those obtained from other districts, nor do we believe that the general average of the householders' existing charges in the metropolitan districts would differ very widely from them.

COST for FIVE YEARS of making, mending, and cleansing Drains, clearing Cesspools and repairing the Water-pipes, Butts, &c.:—

PARISHES.	Number of Answers	For making Drains.	For mending and cleansing Drains.	For cleansing Cesspools.	For repairing Water-pipes, Butts, and Cisterns	Cost of Water Supply.
		£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.
AVERAGE PER HOUSE.						
Parish of St. George the Martyr, Southwark.	101	6 19 7½				
	215	..	4 0 7¼			
	203	..	..	3 3 8		
	253	..	..	..	2 0 10¼	
Parish of St. James's.	260	11 3 0				
	356	..	7 11 7			
	155	..	..	8 3 0		
	356	..	..	..	8 3 7	
Parish of St. Ann's, Soho.	144	12 2 4				
	367	..	3 5 4¼			
	159	..	..	3 17 10¼		
	261	..	..	..	4 2 9	

Cost for Five Years of making, mending, and cleansing Drains, clearing Cesspools, and repairing the Water-pipes, Butts, &c.

PARISHES.	Number of Answers	For making Drains.	For mending and cleansing Drains.	For cleansing Cesspools.	For repairing Water-pipes, Butts, and Cisterns.	Cost of Water Supply.
		£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.
AVERAGE FOR ONE YEAR.						
Parish of St. George the Martyr, Southwark.	101	1 7 11				
	215	..	0 16 1			
	203	..	..	0 12 9		
	253	..	..	..	0 8 2	
	2,064	..	..	..	..	1 7 9
Parish of St. James's.	260	2 4 7				
	356	..	1 10 0¼			
	155	..	..	1 12 7¼		
	356	..	..	..	1 12 8½	
	1,885	..	..	..	..	3 0 2
Parish of St. Ann's, Soho.	144	2 8 5½				
	367	..	0 13 1			
	159	..	..	0 15 7		
	261	..	..	..	0 16 7	
	1,173	..	..	..	..	1 17 5
Average of the above three Parishes	..	2 0 4	0 19 8¾	1 0 4	0 19 2	2 1 9
Or, per week. . .	..	0 0 9¼	0 0 4½	0 0 4¾	0 0 4½	0 0 9¾

Thus whilst we see in an old district or parish in the interior of the metropolis, that the very repairs of the existing house-drains cost 4½*d.* per week, that the repairs of water-butts and cisterns cost also 4½*d.* per week, that the expense of the cleansing of cesspools amounts to 4¾*d.* per week, that of the water supply to 9¾*d.* per week, and the making of the drains to nearly as much, the estimate in detail of new and combined works for Richmond, a suburban district, where the circumstances are not favourable to economy, a large proportion of the houses being detached and widely spread, and the lengths of pipeage for drainage and water supply much greater than in a crowded district, does not exceed altogether 4¼*d.* per week, including public and main sewers, road and subsoil drains, house-drainage, abolition of cesspools, construction of water-closets, and supply of water.

The saving on combined works, as compared with separate works, would, for effecting the improvements above enumerated, amount to about one quarter of a

million, chiefly on earth-works. It is highly probable that in new districts, and with new services, the total saving would, within five or six years after the combined works had been brought into complete operation, amount to the whole expense of the outlay, including the purchase money of the existing water-works at any fair valuation; taking into account the saving to the rate-payers from the diminution of preventible disease, and from a proper system of administration.

In respect to the higher and middle class of consumers, and indeed all who are at present supplied with water by the Companies, we consider, that inasmuch as they would be benefited by a change of system, which would give them the advantages of an improvement in the qualities of water, in addition to the several advantages above specified, including a material diminution of the risk of loss from fire, whatsoever reductions were obtained in the annual charges of managing several establishments should go in reduction of sewers' rates, or in defraying the expense of improvements in drainage necessary for the completion of combined works.

With reference to domestic savings, by the use of soft instead of hard water, the expense of soap will be reduced one-half; the economy in tea will be as five to three, and the saving in all other culinary operations will be in like proportion.

With reference to the expense of works, supposing them to be carried into effect *de novo,* we have entire confidence in the estimates of our inspectors, though as yet those estimates must be received as proximate.

There appear now to be no engineering uncertainties as to the practicability, nor any doubt as to the sanitary results of combined works; the difficulties to be met are legislative and administrative.

Adopting the general administrative principle established in the First Report of the Metropolitan Sanitary Commissioners, and sanctioned by Parliament in the Public Health Act, that works for water supply and the removal of soil or surplus water should be combined, and placed under one and the same management; we have next to consider the modifications of the Public Health Act which may be required from

the specialties to be provided for in the application of the same principles to the metropolis.

The general course of legislation for the improvement of local administration has of late been to consolidate local administrative bodies, and extend administrative areas; to ensure the individual attention of competent and responsible paid officers; to protect and secure rights of appeal to minorities; to raise new securities for protecting public interests against the narrow selfishness which is apt to predominate in small communities. The consolidation of old and creation of new local administrative bodies under the Public Health Act are analogous in principle to the consolidation of old functions and the creation of new local administrative bodies under the Poor Law Amendment Act.

The application of the like administrative machinery to the metropolis, appears to us, however, to be precluded by its vast magnitude and extensive relations, by the necessity for works as extensive, which must for the sake of efficiency and economy be under one and the same control, as being extraordinary in their nature, and requiring special qualifications and undivided attention for their superintendence and execution. Any attempt to execute the proposed works for the capital by the administrative machinery which is sufficient for provincial towns, would open new and large political questions, the settlement of which, and the getting any such new administrative body or bodies into action for the metropolis would, we apprehend, greatly delay the application of remedies, and prolong the sanitary evils of the population. We are, therefore, unprepared to recommend any deviation from the usual course, that, namely, of making a special provision for the metropolis. We must, however, express a decided opinion, that under the existing circumstances of the metropolis, public responsibility to the ratepayers will be best secured through Parliament.

Such has been the view hitherto taken of the specialties of the metropolis, that all previous legislation has dealt with it as an exception to the ordinary recognized principles of local administration.

The metropolis is considered as the seat of parlia-

ment, law and commerce, and as the occasional residence of the population of the whole empire. From these circumstances, as well as from its magnitude, its administration has always been kept, and that with the public assent, within the control of Parliament and Government, to an extent which is unusual with relation to any provincial town.

It is this perception of the national position of the metropolis, that has caused public applications and demands for interference to be made to Government and Parliament which would be deemed extraordinary if made in the case of any provincial city. For example, the public loudly demanded that a Commission should be issued to examine the subject of the supply of water in the metropolis in 1828, and such a Commission was appointed. About the same time the Government was called upon to break up the parochial nightly watch, and place the whole metropolitan police in a state of efficiency and responsibility, to ensure the security of public institutions, of property, and of interests, which were felt not to be local but national. Still more recently, Government and Parliament have been called upon to regulate the practice of interment as a higher subject of police, involving public health and decorum; and they have been further required to interfere for the public protection by causing a better regulation of the public markets of the metropolis. When the practice of lighting by gas was introduced, and when great danger from its use was apprehended, Parliament introduced provisions in relation to Acts to the supply of gas to the metropolis, charging the Secretary of State with a power of control; precautions which were not deemed necessary in like measures for provincial towns.

Unless we widely misjudge, similar public considerations are strictly applicable to the subject of the present inquiry, and these stand opposed to such proposals as have been made to commit the supply of water to Vestries and Local Boards instituted for the administration of relief to the poor.

One of the necessities for special provision in this case arises from the nature of the subject matter of consideration—water.

We start with the assumption that by the law of England water flowing in a stream is *publici juris*, that is to say, a thing which as property belongs to no individual, but the use to all. Blackstone includes it amongst those things which, after all, "notwithstanding the general "introduction and continuance of property, must still "unavoidably remain in common; such are the ele-"ments of light, air, and water, being such wherein "nothing but a kind of usufructuary property is "capable of being had." It is an implied duty of the Supreme Executive, or the State, to regulate the supply, the distribution, and the discharge, or removal of water. The necessary regulation of collection and transport of the element, not only as between one patch of land and another, but between one district and another, is inconsistent with exclusive and absolute local rights, and requires that there should be a power of direction and arbitration superior to the right of individual ownership, as well as of different independent administrative jurisdictions.

The unlimited extent to which even usufructuary rights over waters have been allowed to individuals, will be found to be in dereliction of sound principles of jurisprudence.

These rights giving powers for the exaction of undue payments for permission to open outfalls and clear away obstructions, stand as barriers to the improvement of property by the exercise of proper rights of easement for general drainage works; they also unduly impede the collection of the common element for public supplies, as well as its proper distribution for agricultural purposes.

It has from the earliest times been recognized as the duty of Government to take cognizance of running waters. This duty was entirely performed by the issue of commissions of sewers for works on a large scale, and also in writs, *de acquæ ductu*, for the regulation of water distribution, which in the earlier periods was effected by works on a smaller scale.*

---

* The following examples are taken from Mr. T. Duffus Hardy's collections:—*Parliament Roll*, 10 *Hen. VI.*, *No.* 21.—Prior of Charterhouse, London, licensed to hold a fountain' &c., at Iseldon, and make subter-

From the earliest times the regulation of the supply of water to town populations has rested on the same principles as those on which the maintenance of the highways was founded, and has been dealt with as a public duty. In Rome it was the charge of the Ædile, who was armed with extraordinary powers for its execution. In the course of examinations under the Public Health Act, we find examples of the intervention of the Crown for the regulation of supplies of water even in the provincial towns in England. The concessions of powers in respect to water distribution must have been strictly *concessions* made in consideration of services to be performed. Although in periods of a low state of public administration, or of ill-informed public opinion, such concessions may have led to an earlier extension of supplies to the population than if they had been left to the chances of such provision as might be made for them by public authority, there is no reason to conclude that the maintenance of Companies, based on such concessions, and

raneous conduits therefrom with pipes of lead along the highway, with free entry to repair the same. *Parliament Roll*, 23 *Hen VI*, *m.* 13.—Prior of Barnwell authorised to alienate land, to lay pipes, &c., to make an aqueduct. *Patent*, 28 *Hen III.*, *m.* 4.—From the aqueduct which the King made to his Great Hall at Westminster, he gives Edward, son of Odo, permission to have a pipe, of the size of a goose-quill, into his Court at Westminster. *Inquisition*, 20 *Edw. I.*, *No.* 50.—Writ to the Sheriff of Northampton, commanding him to inquire whether it be to the loss or nuisance of the King, or any other person, if the King grant the Prior and Convent of St. Andrew, Northampton, permission to bring a water-course, which is outside the town of Northampton, by a subterraneous conduit into their priory; the jury return that no loss nor nuisance will arise. *Patent*, 35 *Edw. I.*, *m.* 9, *d.*—Writ to Roger de Brabazon, Ralph de Sandwich, and John Le Blund, Mayor of London, by which they are commanded to go with the aldermen and sheriffs to see and to remove the obstructions and nuisances in the course of the water of Flete, complaints having been made to the King that it is so choked up with filth thrown into it, and impeded by a quay erected by the Templars for their mills near Castle Baynard, that barges can no longer pass up the water from the Thames to Holborn-bridge, with wine, corn, &c. *Patent*, 3 *Edw. III.*, *p.* 1, *m.* 5, *dorso*—Writ to Thomas de Sibthorp, associating him with Henry de Fenton, William Disney, Ralph de St. Lando, Brian de Hertheby, William de Lund, and William de Merston, appointed to remove obstructions in the course of the water of Wythom, between Cleypol and Lincoln, and to enlarge it to the width of 40 or 30 feet between the banks, and to the depth of 10 feet, and to make inquiries by men of the county, &c., by whose default the course has been obstructed, and to levy a rate on those who shall be benefited by the enlargement, according to their tenure, for the clearing out ditches, repair of bridges, causeways, &c.

supplying water for purposes of trading profit, is necessary, whenever there is the requisite knowledge or public spirit on the part of the authorities to provide for an object eminently of public concern, with no other consideration than public interests.

We apprehend, however, that the intervention of adventurers and companies with crude plans must have operated injuriously in facilitating and promoting a dereliction of public duty; for had there been no such intervention, we cannot but believe that increasing public necessities must have led to recognition of the duty in its true light, as one of primary, not of minor and incidental importance. With but a moderate amount of principle and attention on the part of the executive, it is scarcely possible that the poorer population could have been left in their present condition, or that the middle and higher classes could have been burthened with the present charges, rendered necessary by multiplied capitals and defective and unnecessary works on the same field of supply.

Notwithstanding the general advance of the arts, we cannot concede that the public are indebted to the water Companies for any material improvements of this branch of them, and we must, for securing to the populations of large towns water of superior purity, still revert to the principles of public works of water supply constructed with this view at the seats of the Roman empire, those namely, of conduct in covered conduits, and storage in covered instead of open reservoirs.

Captain Vetch describes and remarks on the method of conducting water in open earthen cuttings for the supply of a town, as in the New River waterworks:—

The New River or canal is about 18 feet wide and 4 feet deep, and extends from the site of the balance-engine, at the River Lea, near Ware, to the New River Head, at Clerkenwell, over a tortuous length of about 39 miles, while the distance by a straight line is only about half as much; the water is received from the Lea on a level of about 100 feet above high-water mark in the Thames, and is delivered at Clerkenwell at 84 feet above the same, or with a total descent of 16 feet, for though the inclination of the surface of the water is graduated to a descent of 3 inches

U

per mile, or 10 feet in the whole distance, there are some bays which add 6 feet more to the descent.

He states that—

A great objection to the conveyance of water for domestic purposes in an open earthen channel is, that the water must have a comparatively slow motion, to prevent the current wearing the channel-bed, and bringing in turbid water.

He adds—

In the warm season, so long and broad a surface exposed to the atmosphere gets heated to a degree favourable to the production of vegetable and animal life of the lower forms, and also in giving rise to a considerable quantity of waste from evaporation. The high temperature of the water further facilitates the decoction of leaves and other vegetable matters, which get blown into the New River, to the manifest injury of the water; but there are other pollutions of a worse character, to which all open canals are subject. It is true the New River Company have five acres of settling pools at Clerkenwell, and 38 at Newington, for the deposit of solid matters, but exposed as such broad surfaces must be to the summer heats, it may be doubted if the tendency thus afforded to the germination of animal and vegetable life and decoction of vegetable matters, do not create more evil than good. Such are the objections to all open water conduits conducted in earthen channels, the deficiencies of which will however be still better appreciated by a contrast with the qualifications that may be obtained for the same water if conveyed in covered channels constructed of stone or-brickwork, and conducted in straight lines, with an uniform and efficient descent, crossing valleys on embankments or arcades, and piercing hills by tunnels or adits; for example, the water of the river Lea might be conducted to London in such a channel, from Ware, at a distance of 20 miles instead of 40, and with a speed of one mile per hour instead of half a mile, that is, the transit would be accomplished in 20 hours instead of 80; and during its course it would receive no heat from the atmosphere, but, coming most of the distance in a tunnel, the water would arrive as cool as when delivered from the spring; it could receive pollutions of no kind in its course, nor would it be subject to waste from evaporation, being exposed neither to light nor heat, no tendency would be created to germinate animal or vegetable life, to which also the increased velocity of current would serve as a preventative, and the water remaining pure, no settling tanks would be required, but simply distributing basins; much greater things may, however, be done for supplying London with pure water than the mere contrast now noted.

Though the water of the Grand Junction Canal is fœtid at times—though in other canals the water which is limpid at its source becomes, in its course in

these open cuttings, so discoloured with various impurities that gentlemen would revolt at the idea of the introduction of such water at their own tables, yet we have had various schemes of the same kind for the introduction of Thames water for domestic use into the Metropolis, and canal water for the domestic supply of other towns, urgently pressed by engineers, and adopted by local authorities. We have found it our duty to object to them. Claims are nevertheless preferred in respect to such works as public improvements. Such a work as the New River was not so in this respect even at the time of its construction. At that time the remains of the Roman aqueducts were visible, and their fame was known to the whole world. An engineer with qualifications to direct such works is bound to know what has already been done, and the principles already established. In the Roman works the superiority of a covered channel of conveyance had been established. Even if the same sources of supply as those taken for the "New River" were eligible, and if those works belonged to the public, they ought to be abandoned, and the Roman principle of covered channels reverted to, as Captain Vetch proposes.

The principle of covered conveyance, which suggests itself upon a due consideration of the qualities of water required, except in the case of mountain descents or quick conveyance through elevated or open districts, was extended by the Romans to the storage reservoirs, where English engineers invariably neglect it. The services of Captain Vetch as an engineer in Spain, must have made him acquainted with the Roman remains of covered reservoirs there, and the advantages of preserving water in deep covered cisterns under ground according to the Roman practice. The covered reservoirs or cisternæ at Rome were immense works, adorned with architectural decorations. Constantinople had covered reservoirs or cisternæ, holding, at the least, five hundred millions of gallons. One of these reservoirs, which still remains, is described as constructed of brick, and covered with cememt. It has a vaulted roof, supported by 336 marble columns,

of the Corinthian order, 40 feet 9 inches high. Arches of brick rested upon the capitals, which are surmounted by a massive marble abacus. These columns are placed in rows, 12 feet apart; longitudinally there are 12 ranges, and latitudinally 28. The cistern is 336 feet in length, 180 to 200 feet broad, consequently its cubical contents, to the top of the capitals of the column, would be 3,861,144 cubic feet, or it would hold 25,000,000 of gallons of water. This edifice, with its groined vaulting, would be about as capacious as one of our cathedrals.

Though the Roman arrangements with their architectural decorations internal and external were executed at an immensely greater expense than works upon the same principles of covered conveyance might now be executed for, yet it appears probable that the expense lavished upon them was not greater than that incurred upon our works, which do not possess the sanitary advantages of maintaining the purity and coolness of the water, and while they make no pretensions to the elevating effect of the architectural decorations. The expense of conflicts to obtain private Acts for the metropolitan water Companies, and the waste caused by unnecessary multiplication of capitals and works on the same field of supply, would have sufficed to have constructed works of even greater magnificence than those of Rome. The expense of obtaining the local Act for the water supply of Liverpool alone, and of the subsequent local conflicts which have taken place upon the measure by which it is proposed to bring the water within the town in an uncovered reservoir, would have sufficed for the construction of a covered cistern there, as capacious and (with the exception of the marble columns,) as magnificent as that of Hadrian at Constantinople.

In addition to the principles of covered conveyance and storage to which it is desirable we should revert, we have already indicated the superior care and skill displayed in one point of the Roman distributory apparatus, in the substitution of earthenware for metal service-pipes. It has been our duty to point

out the pollutions arising from the general practice of the retention of water in open house-cisterns: we find that Pliny expressed his surprise at the negligence of those who use such a method.

One consequence of the dereliction of duty involved in the abandonment to Companies of the water supply of towns as a matter of profit, is that the inhabitants are charged not as they would be if they had merely to pay the cost of the service, but according to the extent of their necessities and to the powers of exaction for supplying them. Thus, we have seen cases in which the actual cost of raising water to the tops of houses for a whole year being only 4*d.*, the Companies exact for high delivery from 10*s* up to several pounds, not upon any principle of remuneration for the actual cost of service, but at a rate determined by the necessities of the consumer, and his presumed capacity of paying. The actual cost of procuring extra supplies of water for watering roads is not greater than the extra cost of pumping, and amounts probably, if the height of delivery be 10 feet, to 2*d.* for 400 tons; but the water being sold for what it may fetch, and it being estimated that any price may be obtained, so it be below the expense of hand-labour, it is charged from 9*d.* to 1*s.* per 1,000 gallons, or 50 times the actual expense of the extra service.

As an illustration of the mode of charging by necessities without any reference to the cost of service performed, it may be mentioned that the sale price of water, according to the Nottingham scale, is 3*d.* per 1000 gallons. The consumption of water in a properly constructed water-closet would be about five gallons per diem, and at the above rate the charge should not therefore exceed 6*d.* per annum. If the charge were made only with reference to the extra expense of pumping this additional quantity of water, it would amount to a little more than a farthing per annum; whereas powers are constantly inserted in local Acts to charge for water-closets 8*s.* and 10*s.* per annum, at which price a constant and unlimited supply could be given at the Nottingham rate, with a profit of 5 per

cent., to two houses of the lower class. This single excessive charge would suffice to prevent the most important measure of sanitary improvement—the abolition of cesspools in the poorest and worst-conditioned districts.

By the exclusive occupation of a district, which the Companies have accomplished by arrangements between themselves, trade, in the ordinary acceptation of the term, which implies choice of a market, or an open market, is extinguished; the consumers must take the water-supply at such a price as the Company choose to exact, or provide the water for themselves by sending for it by cart or other means to the river, or to distant springs, a course impracticable for individuals, much less for any number of inhabitants of a large metropolis. Even a public body, such as the Sewers Commission, were in a position similar to that of individuals, as regards the trading Companies, free, namely, either to accept the Companies' own terms, upon each particular application for water, or to adopt their only alternative of a large and disproportionate outlay for the attainment of one object. In considering the important sanitary effect of speedy and effectual surface cleansing and the removal of refuse in water, the mode of charging and constitution of the existing Companies, are found to present insuperable barriers to the prosecution of such improvements with their aid or by their means.

The abandonment of the water supply to private Companies involves the disregard of the public interests on important points, wherever the promise of trading profit does not arise, or where the continuance of such profit may be threatened. Thus, we have been informed by Mr. Payne, the coroner for the City of London and Southwark, that in the course of inquests held there on the causes of fires, the many cases of loss of time before turncocks belonging to the water Company could be found to liberate the supply of water, have over and over again led to inquiry by juries, "What objection there would be to leaving keys of the plugs with the police?" The Company has objected to do so on the ground

that the police were unacquainted with their system of works, which necessitates, on the opening of one cock, attention to others, to prevent derangement and waste of water. Under the system of intermittent supply, where one set of pipes are charged and another empty there might be some derangement, but under a system of constant supply, where all the pipes are charged, no such inconvenience is sustained. Here, with the intermittent system, the public safety is compromised for considerations which have no apparent foundation but in trading profit.

The "principle of trade" and trading considerations are wholly repugnant to improvements in detail from which no immediate profit can be ensured to shareholders. Intelligent officers and directors have admitted their desire to see improvements adopted, but, as there was no direct profit to be obtained from them, they have expressed their despair of being able to get shareholders to adopt them.

The common constitution of trading Companies is moreover such as to preclude their providing for household supplies as cheaply as they may be provided for under public authority. The service being made a matter of trade, and the adoption of it being therefore voluntary on the part of the inhabitants such adoption is commonly slow, and chiefly by the more intelligent and wealthy inhabitants who are few in number. The owners of smaller tenements, who are poor, to whom immediate outlays are the most inconvenient, and who, from their houses having no sinks or drains for the discharge of soil water, have frequently to make the largest proportional outlay, resist, as strenuously as they can, an extension of supplies to their own premises, and generally succeed. Now, in many large districts, these smaller tenements, from their greater number, produce, at a poundage rate, as great a sum as all the middle and higher class of houses put together. For example, in the parish of Bethnal Green, the average rental of houses in the whole parish is only 9*l.* per annum, and those below that rental would produce half the rate.

The proportion of the several classes of houses to each other is as under:—

ST. MATTHEW, BETHNAL GREEN.	Number of Houses in each Class.	Proportion of each Class to Total Number.	Produce of Rate at 5 per Cent. on Mean Rental.
			£.
Under 20.	11,490	1 in $1\frac{1}{8}$	4,250
20 and under 50.	884	1 in 14	1,084
50 ,, 100.	40	1 in 310	124
100 ,, 150.	2	1 in 620	12
150 ,, 200.	1	1 in 12,423	9
200 and upwards	6	1 in 2,070	76
Total	12,423		5,555

The water Companies would, perhaps, gain as customers those at and above 50*l.*, and next they would slowly gain those between 50*l.* and 20*l.* Until the great mass of customers are obtained they must either lose money, or throw, if they can, the whole of the establishment charges on such small minorities as are represented above by the numbers at the higher class of rates. During their first progress, they are frequently compelled to impose undue portions of their establishment charges, and the interest of their outlays, upon such incidental necessities for service as have been above alluded to.

The very slow rate at which the pipe-water Companies' supplies are adopted affords an explanation of the fact so frequently observed of the long periods during which some of the Companies go on with little or no dividends, notwithstanding excessively high charges. Another cause of high charges is presented in the fact, that large establishment charges which might, under a public management, be spread over the whole of the metropolis, are and must be borne by each separate Company, concentrated in six or seven fold amount on the limited number of consumers comprised in the sixth or seventh part of the whole field of supply. In addition to these causes of augmentation it is requisite that the Company should charge for the danger to which they are liable of the intrusion of other capitals into their domain. In their own ma-

nagement, for instance, in their neglect of or delay in adopting the suggestions of their own officers, there are frequently what we deem errors even of commercial management (as, for example, the refusal to filter water when that service may be rendered at so small an outlay) by which this danger is augmented, so that the amount of capital now invested in these works appears to be dependent on the hazard of persons maturing schemes of improved supply at reduced charges, and creating confidence in such schemes; in which case the same reduction of charges and depression of shares must ensue as have ensued from similar causes in the case of the metropolitan gas Companies.

Another evil arising from allowing the supply of water to the public being made a subject of profit to trading Companies is, that when this is seen to be so, others, possessors of rights or property, who might have conceded these for the public service at reasonable rates, consider themselves justified in acting upon widely different principles, and in dealing with the Companies as the Companies deal with the public, that is, in exacting payment from them, not according to the service or the value, but according to their necessities. Hence, three or four times the market value of land or other property is obtained; one potent means of extortion being the expense of the procedure for obtaining private Acts, and the threat of opposition, if the terms required are not complied with.

By the execution of these works, however, as public works, the expense of which is defrayed by equal rates, and the necessity for immediate outlays obviated by a distribution of charges, all such risks and delays are saved to the capitalist and the consumer, the middle or higher classes are relieved from undue burthens, and the charges may be at once lowered for all parties.

This multiplication of capitals and establishments on the same field, and the entire failure of each new Company or capital introduced to reduce the prices, have not arisen from any encouragement given by the Legislature to new Companies, for neither the Legis-

lature nor the Government called for the Companies; but the Companies pressed their own claims, made promises of reductions in price and improvement in quality, and the privilege of trading in a corporate capacity was conceded to them, at their own word, and on their own risk.

At a time when there appeared to be little ground for expecting the immediate adoption of the Public Health Act, an association was formed with the view of directing commercial enterprise to the sanitary improvement (not of the metropolis), but of provincial towns, where no such works had yet been provided, and of placing the enterprise upon what was deemed a better footing, namely, by contracting for the performance of *services* for periods renewable on pre-appointed conditions, in return for a comparatively low but secure and immediate payment from uniform rates. It was urged that anything of the nature of privilege or proprietary rights, or other than simple and terminable contracts for service, formed an untenable basis. The principle proposed for adoption, as a commercial law really advantageous to the shareholders, was that of "low rates for "abundant supplies to the whole population, instead of "high charges for restricted supplies to the higher and "middle classes of the community, according to the "common practice." The association comprised, besides noblemen and gentlemen in high public position, several of the most eminent capitalists and merchants in Europe. The scheme happened to be introduced to the money market at an unfavourable time, namely at the commencement of the pressure of railway demands; but considering the very high commercial sanction given to it, the reception it met with in the money market was unfavourable. It sought to effect a combination of local works of drainage, and water supply, and for the disposal of the refuse of towns. It is probable that, with such high support, the Company might have succeeded, to some extent, in more favourable times, but the principle of contract merely for "services" appeared to be a barrier to extensive support, and in the money market it was objected to the

plan that it required too much skill in the management for a joint-stock Company, and embraced more than one object; that the common run of traders or capitalists could only appreciate single or simple objects, which promised the realization of an immediate return for the outlay. Whatever the soundness of the objection founded on the unfitness of a joint-stock Company for the execution of combined works in the case of an association so constituted, and proposing to deal with provincial towns, we have strong and unanimous testimony to the unsuitableness of the existing trading Companies to execute, or even aid in executing combined works for the metropolis.

We believe that it would be found impracticable to execute economically, that is to say speedily as well as efficiently, the required combination of works by any arrangement with the Companies themselves. The objections, moreover, which it will be necessary here to repeat, to the machinery of Courts of Sewers as at present constituted, are, *à fortiori*, applicable to any projects for the execution of combined works of water supply and drainage by commercial Boards.

In the First Metropolitan Sanitary Report an opinion was strongly expressed, in respect to the constitution and procedure of the District Commissioners of Sewers, against their delays, and the reservation of important business for despatch, "unavoidably *en masse*, at fort-"nightly or weekly meetings, by the honorary and ir-"responsible members, who casually attend, instead of "being despatched, from day to day, by paid, compe-"tent, and responsible officers, giving their whole time "and attention to the subject."

Continued observation has strongly confirmed these objections. Delay in ordinary administration may involve inconvenience in the transaction of common business; but we almost every day receive painful evidence that delay in measures of sanitary improvements involves, not merely large pecuniary loss, but, the wide extension of preventible disease and great loss of life.

Time earnestly and unceasingly occupied in the investigations necessary for the preparation of efficient

measures of relief, is not delay, just as crude, unconnected, and therefore expensive measures are not the best speed. The time, however, which elapses during the intervals of intermittent meetings of these Boards is not, and cannot usually be so occupied by honorary members, who, in proportion to their science, practical ability, and competency to deal with any subject to which they may wholly devote themselves, have business of their own which must and does absorb their continued attention. They can only bestow upon the public business an incidental and occasional morning's attendance for two or three hours at a court or a committee meeting. The members of the courts are charged with the initiation of measures of amendment, but the arrangements of their meetings, the number of the members, their demands for explanations, the amount of formal business, the pressure of incidental but emergent affairs, arising from the very defects which require amendment, and which delay it, all preclude the consideration necessary for the initiation of matured measures there. The incidental attention which it is found practicable to obtain is proved to be unequal to the proper investigation of the principles involved in plans proposed by subordinate officers, the consideration of which is necessarily delayed from committee to committee, and court to court, in consequence of the insufficiency of the time which the members of the courts can really give to attain that mastery of facts and experience arising within the department itself, by which alone a safe judgment on the plans may be exercised.

We may repeat on this head an opinion conveyed in our First Sanitary Report, with which we believe the experience of those most concerned will not be found to disagree.

"The more the investigation advances, the more "is it apparent that the progressive improvement and "proper execution of this class of public works, "together with the appliances of hydraulic engineer- "ing, cannot be reasonably expected to be dealt with

"incidentally or collaterally to ordinary occupation, "or even to connected professional pursuits, but require "a degree of special study which not only place them "beyond the sphere of the discussion of popular "administrative bodies, but beyond that of ordinary "professional engineering and architectural practice.

"In justification of this conclusion, and to show the "evil of the perverted application of names of high "general professional authority, we might adduce "examples of the most defective works which have "received their sanction.

"All the improvements which the public have yet "obtained in this branch of public works have been "the result of the special and undivided practical "attention of well-qualified paid officers; and it "appears to us that further improvement must be "sought by the same means, and that one of the chief "objects of future administrative arrangements must "be to secure, protect, and encourage the zealous undi- "vided attention and efficient labour of such officers."

If instead of thirteen Commissioners, meeting at fortnightly or weekly courts, or at still shorter intervals, in committees composed of members unavoidably varying, three competent, paid, and responsible officers met *de die in diem*, and gave, not a part of each day, but the whole of the day and of their undivided attention to the labour, the despatch of business would certainly be at a rate of far more than six times the present speed, while a pecuniary saving would be effected even after the payment of those officers, which would show the present practice of honorary service (implying intermittent service and delay) to be the most grievous public and private waste.

With such evidence of the insufficiency of incidental and intermittent attention, even on the part of gentlemen of European name and the highest qualifications, the imposition of new labour, requiring more sustained attention, could not be proposed.

Since the publication of the First Sanitary Report, preparations of great magnitude and importance for combined works have been made. The completion of

these works must, under any circumstances, have occasioned delay which was clearly foreseen, and consequently palliative measures only were contemplated in the first instance. In reference to these works of palliation it was expressly stated, "If that which may "be done within the time, with every aid and exertion "in carrying out such measures, be little as compared "with the magnitude of the evil, it can scarcely fail to "repay the effort."

We beg leave to recall attention to the further terms of the Report, and to state what has been done upon it, as being important to the present and general object of sanitary improvement:—

"Concurrently with the immediate works of flush-"ing and cleansing which the paid officers may be "enabled to carry out, we expect that the first work "which a consolidated Commission must see the "necessity of directing to be proceeded with would "be the general survey by the officers of the Royal "Engineers, under the direction of the Board of Ord-"nance. Whatsoever may be the modifications of the "authorities having charge of the public works for "drainage and cleansing, or the ulterior measures "which may be adopted, there can be no reasonable "doubt of the execution of the survey being the "measure of paramount and most pressing import-"ance. Until the consolidation of the districts which "we recommend is effected, until the work of the "survey is proceeded with, and further inquiries and "experiments based upon it are made, we do not see "that it will be practicable to make satisfactory proxi-"mate estimates of the extent and expense of the "alterations and adaptations practicable in the old "and erroneously constructed works, or the extent of "new works which may be required to be done for "the purposes in question. Such estimates would be "desirable in order to determine the modifications "of the executive agency for conducting the new "works required. We apprehend that it is only by "such a body as the one we recommend for the whole "of the metropolis, that complete general results, de-

"ducible from a general survey, may be reasonably "expected to be brought out for the future guidance "of this branch of the administration. * * * * "We beg leave to represent the expediency of con- "centrating early the largest practicable force of the "Ordnance survey upon the metropolis."

According to an estimate of some civil engineers, the execution of this measure was to cost a quarter of a million of money and according to another was to have required an expenditure of 100,000*l.*, and have occupied between six and seven years in its completion By the elimination of non-essential work, and the postponement of details not immediately necessary, the survey is in a fair way to be completed in about one-third the time, and at little more than a quarter the expense originally estimated, and it may now be made the means of extensive economies. By the aid of this survey, combined works may now be executed with certainty. Under the present method, according to which water-works are laid down piecemeal, and in disorganized portions, the mains are separated from the other and most important part, the apparatus for the delivery of the water into houses; and under this system the value of an accurate system of levels is not apparent. But by means of the accurate levels set forth on the survey, the inclines and directions of the branches may be determined, with the effect of saving considerable lengths, and of securing the greatest amount of flow and the readiest supply of water at the least cost. By the system of levels, the relation of every minute portion of the work to the whole system, the degree of pressure and strength of apparatus required in any room, the height and force of the jets, and the quantity of water delivered for any purpose on any spot, and the average pressure of the water supply, in any district, may be known and regulated at any period; whilst every workman engaged in the execution of combined works in the dark and densely crowded distiets, may be guided by the survey in laying down house and branch drains for the discharge of soil water at the proper inclinations, and in directions having

correct relation to works often at several miles distant. By the levels taken for this survey, the waste in laying out extensive lines of sewers with no fall, or with falls the wrong way, waste such as that of laying out a table of drainage, including an entire district, in such imperfect relation to other districts as would involve, in the opinion of the chief surveyor, an expense of upwards of 250,000*l.* to set the levels right, may be prevented; and the whole of the public works of the metropolis, including roads, may now be placed in correct relation to other works, and the delay, expense, and uncertainty of special surveys on every occasion will be saved.

By the detailed survey in course of execution on the outline plan furnished by the Ordnance Department, a foundation will be laid for the registration and cheaper transfer of real property, as well as for the more equitable assessments and collections of local rates and taxes, and many other important purposes. Besides this surface survey, a subterranean survey has been made of the form, inclination, and construction of upwards of 400 miles of sewer, and of connected parochial works, of the condition and even existence of which in many cases the various local authorities appeared to have been totally unaware.

By the experimental gaugings and trial works adverted to in the recommendation, it is established that four, five, and six districts (as already explained in evidence), may now be drained effectually at an expense which would only two years before have been incurred for draining one district ineffectually. In respect to the run of soil water, the gaugings and other investigations have proved that of fifty millions of gallons of water pumped into the metropolis nearly thirty are worse than wasted; which shows upon what insufficient data the new schemes for bringing in additional quantities of water generally rest. It is not too much to say, that so far as the investigations under this head have advanced, they will afford a means of saving money, or of averting waste, in the metropolis, to the extent of several millions. The trial works made for

the metropolis are not less available for the guidance of similar works in all provincial towns. Negatively, no less important public service has been rendered by them, in the immediate check given to the progress of unconnected and wasteful works. In one district alone, an expenditure of no less than 300,000*l.* was contemplated for an extension of sewers on the old system of storage of soil water and intermittent discharge, which in fact would have been an extension of the present elongated cesspools, and would still further have depressed the condition of the population.

Examinations were made, tables, plans, and estimates were prepared for the beneficial drainage of the marshes which beset the metropolis, and powerfully contribute to the depression of the health of the population. An extensive collection was made of the results of the most recent experiments in land-drainage; and regulations were prepared for realizing the public sanitary advantages of such works, by the provision of outfalls, and by rendering the survey, with working tables and instructions, available for the accommodation of individual owners and occupiers. Whilst these preparations were made for the relief of sites from surplus and stagnant moisture, injurious to habitations and detrimental to production, trial works were directed and executed to determine better than had practically been done the expense at which the soil-water might be conveyed and distributed as manure, and to make provision for its sale. By these works it was proved, that one hundred tons of liquid manure might be distributed, in less than half an hour, at an expense of 1*s.* 8*d.*, and that in less than an hour all offensive smell was dissipated, from causes which are explained in the important evidence of Professor Way, whereas by the common method of applying manures, the offensive surface evaporation continues for days, and often for weeks, to the loss of the best portions of the manure. The evidence obtained by these trial works, of the fertilizing power of sewer-water, was entirely in corroboration of the experience of nearly half a century, as supplied by

Edinburgh and Milan, and proved the practicability of great improvement upon the methods adopted near those cities.

Whilst these preparations for works have been made, important facilities for improvement in administrative machinery have been gained by the consolidation of the district Commissions. This consolidation has given a large increase of valuable service, with a diminution of expense. The staff of paid officers has been increased, and yet the expenses of management, as compared with the rental of the enlarged district, have been reduced by upwards of 43 per cent., though various new duties are performed for this; but the advantage of this reduction is inconsiderable as compared with the gain in increased efficiency of all work which is dependent on systematic operations on a wide basis.

Though the services gained were rendered by persons engaged in other public and professional occupations, yet they were not unworthy of the eminent men by whom they were rendered. In direct economy, and the restoration of much local administration from extreme waste and disorder, as much was gained as by the consolidation of local and parochial trusts effected under the Metropolitan Road Commission, by which the debts have been paid off, the tolls reduced, and the condition of the roads improved. Until the district Commissions of Sewers had been abolished, it would have been impracticable to execute any comprehensive measures for the sanitary improvement of the labouring classes or general population of the metropolis.

Careful consideration of the nature of these important preparatory works would, we believe, suggest a continuance in the same direction, with such modifications as experience has suggested for the execution of combined works.

The chief objects to be kept in view for the health of the population of the metropolis are simply these: an improved system of water supply, to be effected by the purchase and consolidation of the water Companies' existing works, and by combination of these with the works for the removal of the soil-water and the general

drainage, under the direction and control of such an administrative body as may carry these objects into effect most certainly, speedily, effectually, and economically.

We submit that these objects will be best effected by unity of design and direction in the hands of a very few competent paid officers—competent by their especial knowledge—giving their whole time and attention to the objects to be retained, until they are accomplished; and we believe that responsibility of these officers to the ratepayers, and to all parties interested in the improvements in question, will be best secured through their representatives in Parliament.

It appears, that when dissatisfaction with the water supplies became prevalent, persons engaged in well-sinking on a large scale, or concerned with artesian wells, canvassed the vestrymen of several separate parishes to adopt their schemes of water supply. It is stated that with some vestries they succeeded in getting preparations made for obtaining supplies by authorizing the vestries to levy rates for the construction of parochial water works. Even if the quality and quantity of the suggested supply had been a matter of certainty, it is demonstrable, that such a mode of obtaining it would have been enormously and disproportionately expensive. The Henley scheme and one other scheme were proposed for execution by joint-stock Companies; but the shares not going off sufficiently well in the market, the promoters canvassed the vestries to support a Bill for carrying out their schemes by representative parochial boards empowered to levy rates. In this circumstance we believe originated the plan of a large parochial representative body for the executive works of water supply and other public objects in the metropolis. It is necessary to advert to these facts, as they suggest the first objection to such a scheme, that these bodies would be established to execute works of which they are entirely incompetent to judge.

Having shown the insufficiency of the intermittent attention of persons of the highest general acquirements for the execution of such works, and the neces-

sity of yet more special and constant attention being directed to them, it follows, as a consequence, that the opposite course, which has been pressed for consideration, of subjecting the works to the direction of persons unavoidably of lower information, greater number, and inferior responsibility, changeable from year to year, such as the parochial boards, would defer indefinitely, if it did not entirely destroy, all prospect of improvements commensurate with the position and wants of the metropolitan population. No room for doubt is left as to what would be the effect of placing the works in the hands, or under the direct influence of persons whose own works are proved, upon all preceding inquiries, to be ill-considered, wasteful, and inefficient.

The little attention which the great majority of the inhabitants of the metropolis do or can really give to parochial business, leaves them to the influence of small bodies, who may have any sort of interest in the management of particular business. It is quite possible that members of these Boards may be appointed by the influence of tradesmen and others who are employed by them. Larger works must lead to the exertion of proportionately strenuous influence for the purpose. In reference to the present question, parishes have, it is stated, been canvassed, and successfully by the supporters of various conflicting schemes, several of them, we believe, deriving their supplies from chalk or hard water sources, and some of them from the Thames, which we have felt it to be our duty to declare an unfit source for the permanent supply of the metropolis, at whatever point of the water it may be taken.

One scheme which has met with support, is for the adoption of separate parochial wells, which would subject the rate-payers to disproportionately heavy establishment charges for inferior works.

The promoters of another (the Henley) scheme, state that the principles embodied in their Bill have been affirmed by the vestries of parishes containing 900,000 inhabitants. One of the principles thus affirmed is, that London on both sides of the Thames

must have a vastly increased quantity of water. The evidence has, we apprehend, proved that after accomplishing all the purposes provided for by the proposed scheme, and other important purposes not contemplated by it, the quantity required will be reduced below that now actually supplied to the metropolis; and that any scheme for bringing in a gross supply of upwards of 100 million gallons per diem, displays extreme ignorance of domestic wants and power of consumption, and would, without the provision of means for its removal, aggravate existing sanitary evils. It has already been pointed out, that as an independent work, the Henley scheme would involve an outlay of more than three times the expense which would suffice for obtaining an improved supply of equally pure Thames water. It is to be observed, moreover, that the scheme provides for an expenditure on the management of this separate work, nearly double that which we should propose as necessary for a special commission, to execute the combined works.

We entirely concur in the necessity of securing a responsible administration for the execution of works so important to the health and comfort of the population, as those of water supply.

By a consolidation of the several district Courts of Sewers, which had become substantially representative Boards, the nominations of local representatives being invariably accepted, an approach has certainly been made towards securing a stricter responsibility. By the attention paid to this branch of administration, its proceedings have, for the first time, been brought more distinctly within the view of the public and of the Legislature. Inquiries, such as were never before thought of in relation to the proceedings of the district Sewers Courts, are now made in Parliament on behalf of the public in relation to the Consolidated Commission, with the assurance of their being answered. The proposal to commit the initiation of engineering works and expenditure to representatives from parochial Boards would be not merely to reduce the respon-

sibility to what it was, but practically to destroy all responsibility whatever; for the responsibility to be created is less for misfeasance or malfeasance than for nonfeasance. One principle of the Public Health Act is, that proper protection shall be secured to minorities. On a petition of one-tenth of the rated inhabitants of any place a local investigation may be made, and if a case is proved, the Act may be applied, whether there be a majority of the inhabitants in its favour or not. This principle of the extension of a right of appeal and protection to minorities appears to us to be of the highest importance; but, in respect to the metropolis, we are apprehensive that district bodies, constituting in the whole, large majorities, require protection. The most numerous attacks and deaths from epidemic disease and the severest suffering from preventible causes occur amongst the labouring classes, and who, though as weekly tenants and lodgers, they pay for wretched accommodation the largest amount of rent, namely, 12 and 16 per cent. on the original outlay, yet pay no rates directly, and have no voice in parish affairs. We would submit that, on that account, protection should be extended to them, and that the necessity of this is proved especially by the whole experience acquired during the late visitation of the cholera.

Besides this class of the population, there are the numerous bodies of labourers of every class, native and migrant, provincial visitors, and temporary residents, native and foreign. Besides these, such is the absorbing nature of professional and social pursuits in the metropolis, that the best educated and the most respectable and wealthy of the ratepayers neither can nor do take any part whatsoever in parochial affairs, and in fact know nothing of them, or of the small parties into whose hands such management as there is generally falls.

On the whole then we are of opinion, that the most effective and real responsibility will be secured to the great body of ratepayers, as well as to other permanent and temporary residents in the metropolis,

not by attempting to fix responsibility on a multitude of fluctuating parochial bodies, but by making it direct, through the Government to Parliament.

This responsibility would be augmented by the new provisions already comprehended under the Public Health Act; those, namely, for the publication of explanatory reports and estimates, to which might be added plans and estimates in an accessible shape, for examination, objection, or suggestion, before the execution of works; the execution of works on contract by open tender, not merely for construction, but also for repair and maintenance for terms of years; for public audit, publication of accounts, and annual reports.

We consider that the accounts might be advantageously audited by auditors appointed by the chairmen of the Parochial Unions, and the right of inspection and appeal might be given to them and to individual ratepayers as a security against excess in individual charges.

But inasmuch as distributive charges form one chief means of executing new works, we consider it one essential security against malversation, that the principles expounded in our general Report should, if possible, be extended and strengthened so as to meet the facilities and temptations to waste afforded by the greater magnitude of outlay in the metropolis, and that the sanction of some competent body, distinct from the one charged with the initiation of expenditure, should be required, before any mortgage of rates be allowed.

As one of the Metropolitan Sanitary Commissioners, Professor Owen continued his aid during the present investigation, and we have his concurrence in our conclusions.

Having directed our medical and engineering inspectors to inquire, as closely as the time would permit, into the state of the water supplies of the metropolis; having through them consulted the most recent practical experience of other districts where new supplies of water improved in quality and distribution have been introduced; and having taken an extensive body of evidence thereon, we find, as relates to the quality of the water of the river Thames—

1. That for domestic use it is inferior to the average quality of waters supplied to towns:

2. That its inferiority as a supply for domestic use arises chiefly from an excess of hardness:

3. That even when taken above the reach of pollution from the sewers of the metropolis, it contains an excess, varying with the season, of animal and vegetable matter:

4. That although this latter cause of inferiority may be in part removed or corrected by filtration, the excess of hardness will still remain, rendering this water especially unfit for the following uses, namely, for cleansing the skin, and for the ordinary purposes of washing, by occasioning an excessive consumption of soap; for the preparation of tea, by occasioning waste to the like extent; and for all culinary processes by diminishing their efficiency and increasing their expense:

5. That the quality of the water of the river Lea and of the New River is, in this respect, no better than that of the Thames water taken beyond the influence of the sewage of the metropolis:

6. That the water taken by the Lambeth Company from the Thames opposite Hungerford Market is charged with animal and vegetable impurities, apparently the effect of the discharge of sewer-water, which render it wholly unfit for use, and highly dangerous to the health of the persons who drink it:

7. That of the seven principal Companies by which pipe water is conveyed to the metropolis, four deliver it without previous filtration:

8. That the defects in the quality of the water at present supplied, when collected in its least objectionable condition, and the evils arising from its distribution in the unfiltered state, are all aggravated by the practice of intermittent distribution:

9. That the practice of intermittent distribution occasions, in the case of the better description of houses, the retention of the water in cisterns and butts, and, in that of the poorest classes, in tubs, pitchers, and such other vessels as can be obtained; and, as a consequence

of such retention, the water imbibes soot and dirt, and absorbs the polluted air of the town, and of the offensively close, crowded, and unhealthy localities and rooms in which the poor reside:

10. That, from the inferiority of the water at its source as at present collected, and from the additional pollution and deterioration occasioned by the mode of its distribution, a large proportion of the population is rendered averse to the daily use of water as a beverage, and is inclined and almost forced to the use of fermented liquors and ardent spirits to an extent greatly beyond the consumption of such drinks where purer water is more accessible:

11. That the annual cost of the construction and maintenance in repair of cisterns and their supports and connected apparatus in the houses of the middle and wealthier classes, often exceeds the annual water-rate:

12. That the cost of the pipe-water supply, and the additional expense and inconvenience resulting from the present mode of its distribution, cause the population in some suburban districts to resort for water to open ditches, and in other crowded localities to shallow springs or wells; sources which are subject to increasing pollution from cesspools, from badly constructed house drains and sewers, and from overcrowded grave-yards:

13. That the localization and intensity of cholera in such districts as those alluded to was promoted in a most marked manner by the use of water containing decomposing animal and vegetable matter, derived from sewers, drains, and other impure sources:

14. That the districts most severely visited by epidemic cholera, as well as those most afflicted by ordinary epidemic diseases, are low-lying districts, where, from the defective state of the drainage, there is an excess of damp and of putrid decomposition; and that such excess of damp is aggravated by the waste of water attendant on the intermittent mode of supply; a waste which appears to exceed the whole of the annual rainfall on the inhabited area of the metropolis.

Many practical difficulties having been urged against the substitution of the constant for the intermittent system of water supply in the metropolis, we have particularly examined into the working of the constant system in towns where it is established, and in some of which it has been in operation for 15 and 20 years, and we find—

15. That the waste of water is so far less instead of greater under the system of constant supply, that although the inhabitants have unlimited command of water, and use what they please, though the actual use of water by the inhabitants is greater, the quantity delivered by the Companies is less, frequently less by one-half, in consequence of there being less waste from the more perfect delivery:

16. That the water, under the system of constant supply, is delivered purer and fresher, of a lower temperature in summer, and that it is less subject to frost in winter:

17. That the inconveniences apprehended from the interruption of supply during repairs and alterations are never experienced, the work being executed under such simple precautions that no complaint has ever been known to have been made on this account:

18. That the interruptions of supply which are so constantly experienced on the intermittent system from the waste in the lower districts, from the neglect of turncocks, from limitation of quantity, from inadequate or leaky butts and cisterns, or from deranged ballcocks, are scarcely ever known on the constant system:

19. That the system of constant supply admits of great economy in pipes, as they may, under that system, for the most part, be considerably smaller, and, not being subject to the violent hydraulic jerks of the intermittent system are less liable to burst:

20. That the pipes for the house service may not only be considerably smaller and cheaper, but that the cisterns and apparatus connected therewith, which, in the smaller class of houses, now cost more than the whole public portion of the works, may be entirely dispensed with.

In respect to the quantity of water actually supplied, and to the quantity needed for the domestic use of the metropolitan population, and for other purposes, we have to report—

That in consequence of statements made by several of the Companies of the quantities of water which they pumped for the use of the metropolis, quantities which appeared to be inconsistent with the known habits of the population and the apparent amount of water consumed for domestic purposes, we deemed it desirable to cause the consumption of water in different districts, by different classes of the population, to be gauged from the cisterns and butts, and also the run through house-drains and sewers on days when there was no rainfall.

From these observations it appears,

21. That—whereas it was returned, in 1832, that the average quantity of water delivered to their respective customers by the several Companies was 220 gallons per house or dwelling; and more recently, as returned to us, was stated to be 164 gallons per house or dwelling; that is, 44 millions of gallons per diem for the whole of the metropolis—making allowances for a considerable and injurious waste of water by permeation through badly constructed channels, the results of the gaugings of the run of water through drains and sewers, on days when there is no rainfall, do not appear materially to differ from the later statements of the several Companies as to the quantity of water which is actually pumped into their several districts; while from the gaugings of the quantities of water consumed from cisterns and butts during the intervals of the intermittent delivery, and from the capacity of the storage receptacles themselves, it appears that the average daily consumption does not exceed five gallons per head on the population; and that, with all allowances for the quantities used for manufactures, steam-engines, and other purposes, the gross quantity consumed does not exceed one-half of the quantity delivered:

22. That this waste is a consequence of the present

intermittent mode of supply; and does not take place to any such extent where the constant system of supply has been substituted; and probably may be prevented altogether where the house service-pipes are properly provided and arranged under a system of combined works:

23. That this waste, as now ascertained by official investigation, appears to have gone on without any knowledge of its great amount on the part of the Companies, although it involves a double expense of pumping, and exceeds, as above stated, the whole of the annual rainfall on the covered area of the metropolis:

24. That this waste is of no equivalent benefit for the cleansing of house drains and sewers, inasmuch as, from the inaptitude of these works, owing to their bad construction, for the discharge of water containing matter in suspension, accumulations of decomposing matters do take place in them, to the great injury of the public health; accumulations which, notwithstanding the flow of the waste water through them require to be cleared away by hand-labour, by flushing, or by other means:

25. That the waste water, having sewer matter mixed up with it, permeates through the brick drains and sewers, saturates the sites of houses with polluted water, and keeps up an excess of moisture, which rising into the porous and absorbent walls and plaster of the houses, contributes to render them damp even in the driest weather:

26. That this excess of moisture is aggravated by the extremely defective drainage in the low-lying and worst-conditioned districts, where, as has been already stated, epidemic disease is almost invariably present, and where the recent visitation of epidemic cholera has been the most severe:

27. That, taking into consideration the actual domestic consumption of water by the population of the metropolis, regarding also the extent of the increased supplies needed for various purposes of sanitary improvement not hitherto contemplated by Companies, nor included in new schemes, all the engineering

estimates put forward by private Companies of the quantity of water required for the service of the population appear to be greatly in excess:

28. That there appears to be no probable demand for a general average consumption of water exceeding the present rate for houses of the higher class, namely, about 75 gallons per house per diem, or in all 22 millions of gallons per diem, inclusive of the increased supply which will be necessary on the abolition of cesspools; and that, estimating the additional requirements for baths, for street cleansing, for large consumers, for fires, and for other purposes, the whole quantity of water needed under an improved system of distribution does not exceed 40 millions of gallons per diem:

29. That it appears that the resolutions of parochial meetings and the statements of the promoters of new Companies, alleging a deficiency in the total amount of water already introduced, and proposing to bring in additional supplies, have been made in ignorance of the actual present domestic consumption of the population and of what is really needed, according to the best information, for the execution of practical measures of sanitary improvement:

30. That the several schemes which propose to bring in more water in addition to the quantity now wasted, and to make such additions mainly from the same sources which supply the water now generally consumed, without reference to improvements in the system of domestic distribution, and without combination with improved drainage-works for the removal of the waste water, would aggravate the existing sanitary evils, and increase the excessive charges already incurred for defective works constructed in ignorance.

Having particularly examined the statements as to the increased quantities of water required for the flushing of drains and sewers, and the working of an improved system of drainage, we find,—

31. That upon a system of drainage such as that at present in use, consisting of brick house-drains and sewers which cause accumulations of decomposing de-

posit, there would be required, for the intermittent removal of those accumulations by flushing, considerable additions to the present quantities of pipe water pumped in for the supply of the metropolis, but that any system of house or main drainage which occasions the accumulation of decomposing refuse, and renders necessary the continuance of the practice of intermittent flushing, is in itself highly injurious to the public health, and ought to be prevented.

32. That recent trial-works have placed beyond doubt the soundness of the conclusion of the Metropolitan Sanitary Commissioners; namely, that systematically adjusted tubular house-drains and sewers are kept clear of deposit by the force of the soil or sewer water alone, when conducted away at proper levels; and that no addition of water is required for this purpose.

With reference to those extensive districts of the metropolis, the levels of which are below high-water mark, where the sewer water is at present penned up until it can be discharged at low water, and where putrifying deposit is accumulated in the sewers in consequence of the flow being arrested during high water, it appears,—

33. That it will require no addition of water, and certainly no increased expense in pumping, to cause such a continuous flow of the waste water as will prevent deposit; and that this prevention of deposit is the true object to be aimed at, and not the supply of additional quantities of water to remove, by flushing, deposit which ought not to have been allowed to accumulate.

34. That besides the great injury to the public health from the ponding up of sewer-water and the consequent conversion of large sewers and reservoirs into extended cesspools; and besides the waste of water and the expense of pumping it into the district for the removal of accumulations, the intermittent system of draining the districts below high water-mark by gravitation, without the aid of pumping for their

relief, must necessitate the continued pollution of the Thames, and obstruct or delay the application of the refuse as manure.

35. That, except in extreme cases of absolute deficiency, the pumping in of additional supplies of water, before properly constructed house drains are laid down for its removal, would, by increasing damp, still further deteriorate the sanitary condition of the population, and occasion still greater dilapidations and injury to tenements.

36. That the separation of works of pipe-water supply from those for the removal of waste water occasions delay in the execution of works of primary importance for sanitary improvements, as well as increased expense.

37. That it appears that while the expense of sewers and drains is reduced by an improved tubular system of drainage, the expense of earth-work, of digging and of making good, is one-half of the total expense, and that, therefore, the separate laying down of water-mains and drainage-mains must frequently cause this last portion of the expense to be materially increased.

38. That, on these grounds, and on the principles already recognised, the only way of securing systematic works with economy and efficiency, as well as with the least delay, will be to consolidate under one and the same public management, the whole works for the supply of water, and for the drainage of the metropolis.

39. That it is essential to the economy and efficiency of all such works that the whole distributory apparatus, small as well as large, service-pipes, and house-drains, together with water-mains, public drains and sewers, should be laid down under one system, and kept in action under one supervision.

40. That it appears from the examination of improved works which have been in operation for a sufficient length of time to test their efficacy, and from detailed estimates made by different competent engineering officers upon house-to-house examinations of the worst-conditioned districts, that combined works,

comprising a water-pipe for the service of each house, a sink, a drain, and waste-pipe, and a soil-pan or water-closet apparatus, may be laid down and maintained in action at a cost, not exceeding, on the average, three-halfpence per week, or less than half the average expense of cleansing the cesspool for any single tenement:

41. That the general survey being now sufficiently advanced, such works may be executed for separate districts, without waiting for the completion of any general measure or plan of main sewers.

Having considered the evidence in relation to the qualities of the water requisite for the supply of the metropolis, we find :—

42. That in addition to the properties of clearness and freedom from animal and vegetable matter, which is apt to pass into decomposition and to prove injurious to health, one of the most essential properties of water is *softness*, or freedom from lime and other substances productive of what is termed hardness:

43. That having made careful and extensive inquiries, with the aid of the Department of the Ordnance Geological Survey, as to the most suitable sources of supply, having had those districts which appeared to be the most eligible specially examined by our engineering inspectors, with other aid, we find upon their unanimous testimony that from a tract of upwards of 150 square miles of gathering ground, there is derivable a supply nearly double the present actual domestic consumption, of a quality varying from one-tenth to one-third the hardness of Thames water, and of a purity equalling the general average of the improved soft water supplies of the districts which have yet been brought under examination:

44. That water obtained from silicious sands, such as those which cover the tract above described is proved to be of a quality only equalled in excellence by the water derived from mountain granite rocks, or slate rocks or other surfaces of the primitive formations:

45. That, upon the best estimates which have been obtained, this water may be brought to the metropolis, and delivered pure and filtered into each house, on the system of constant supply at high pressure; and, at the same time, on the plan of combined works, the waste water may be removed by a proper system of drainage, at a rate not exceeding an average of 3*d.* or 4*d.* per week per house, or from 30 to 50 per cent. less than the present charges for defective water supply alone:

46. That the saving in soap, from the use of soft water, in the operation of washing (the expense of washing linen and other clothes being estimated, at an average of 1*s.* per head per week, to be nearly 5,000,000*l.* per annum on the population of the metropolis) would be probably equivalent to the whole of the money expended at present in the water-supply:

47. That the saving in tea from the use of soft water may be estimated at about one-third of the tea consumed in the metropolis:

48. That other culinary operations would be much facilitated by the use of soft water:

49. That soft water is peculiarly suitable for baths as well as for washing:

50. That soft water would prevent those incrustations and deposits in boilers and pipes, which render hard water unsuitable for manufacturing purposes.

We therefore advise the rejection of all the schemes promoted by water Companies or by parochial vestries and associations, which adopt, as sources of supply, the Thames and its tributaries of the same degree of hardness, wells, and springs from the chalk or other formations which impart the quality of hardness:

And further, whilst we believe that Thames water, taken up beyond the influence of the metropolitan drainage, and filtered, may be used without injury to the public health, and may be employed temporarily until other sources can be laid under contribution, we advise that Thames water, and other water of like quality, as to hardness, be as early as practicable abandoned.

In respect to the existing Companies which have no property in any of the sources of water supply, but whose capital is invested in engines and distributory apparatus, we recommend that their plants should be purchased, but we are not prepared to recommend any pre-appointed terms of purchase ; and we find—

51. That, if the management of the water-supply be consolidated, five if not six out of the seven principal pumping establishments may be discontinued, and an expenditure of from 80,000*l.* to 100,000*l.* per annum saved by consolidating the management of these works and connecting them with combined works of drainage and sewerage, and that further reductions may be made in the expenses of these latter establishments.

Having considered, as required under the Metropolitan Sanitary Commission, the means of supplying water to extinguish fires, and having examined the practical experience of improved works in relation thereto in other towns, we find—

52. That the inadequacy of the supplies of water under the intermittent system occasions great danger to life and property, but that by arrangements which are practicable under a system of constant supply at high pressure, the whole force of the water in the mains may be brought to bear at any point for extinguishing fires in from one to five minutes, or in about one-fourth the time that it takes the best appointed fire-engines now to gain the spot and be in action after the alarm of fire has been given:

53. That, judging from the experience of various places where improved arrangements have been put in practice, it appears that by the general adoption of these arrangements more than two-thirds of the fires which now occur in the metropolis may be extinguished, before any extensive damage takes place:

54. That the insurance risks on life and property may be diminished in a yet greater proportion:

55. That the crime of incendiarism may be checked, and that these consequences alone, were there no other advantages to be obtained, would render it worth while

to make the change from the intermittent to the constant system:

56. That these advantages may be best given by the same means by which a more perfect and cheaper surface cleansing of courts, alleys, foot-pavements, and carriage ways than that by hand may be effected, namely, by jets of water distributed under high pressure.

Having considered the most eligible administrative provisions for the execution of the required works, we concur in the principles recommended by the Commission of Inquiry as to the best means of Improving the Health of Towns, and confirmed by Parliament in the Public Health Act, viz.:

57. That the works of water supply, and those for drainage, or the removal of soil or waste water, should be carried into effect by one and the same administrative body:

58. But that the magnitude of the metropolis, the diversity of its local jurisdictions, and its position as the seat of Government, and the occasional residence of persons from all parts of the empire, the large minorities requiring protection, and the unaccustomed magnitude of the requisite outlay, render distinct and special provisions necessary for it, and that the amendments required may be most speedily, safely, and economically executed by special or by provisional arrangements:

59. That a general survey under the direction of the engineers of the Board of Ordnance, and other surveys, trial works, and preparations essential to the safe and economical execution of combined works of water supply having been completed, under the direction of the consolidated Metropolitan Sewers' Commission, such combined works may now be executed and maintained at a lower rate of charge per house than has heretofore been incurred for any of their various branches executed separately:

60. That the initiation and executive direction of such works by members, however highly qualified,

giving casual attendance at meetings held weekly or fortnightly, causes grievous delay, and that in cases in which measures for preventing disease or arresting its progress, require the utmost promptitude:

61. That considering the great loss and suffering incurred by the delay in carrying the required works into execution, it will be expedient to confide their further preparation and superintendence to a few competent and responsible officers, of whom a certain proportion should be paid, giving their whole time and attention to the subject. That the whole of these works be carried into execution by contract upon open tenders, not merely for the construction of the works, but for maintaining them in good action and repair for terms of years:

62. That the means provided by the Public Health Act for giving publicity to plans and estimates of intended works, with opportunities of suggestion and appeal, be extended to the works proposed for the sanitary improvement of the metropolis:

63. That the proper execution of the works will be best guaranteed, the responsibility of the persons charged with their execution best ensured, and the interest of the poorest classes of the population (the inhabitants of the most depressed districts, who though they pay no direct local rates pay heavy rents), will be best guarded in the special case of the metropolis, at all events provisionally, by the direct control of Parliament; the importance of the proposed measures to the health, convenience, and comfort of large masses of the population, the magnitude of the required constructions, the amount of outlay, and the dangers of failure and waste as well as delay being, from experience of separate works already constructed, such as to render it necessary that the highest order of continued and undivided attention and responsibility should be secured for the execution of such works as this Report recommends.

All which we whose names are hereunder subscribed, being the members of the General Board of Health at the time this investigation was commenced and in great measure completed, beg leave to certify.

CARLISLE.
ASHLEY.
EDWIN CHADWICK.
T. SOUTHWOOD SMITH.

Gwydyr House,
28*th May* 1850.